National Harbours Board

(Port of Vancouver)

Environmental Impact Assessment

of

Roberts Bank Port Expansion

Volume 4

Appendix B

The Existing Biological Environment

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B1.0 INTRODUCTION

This appendix assesses the existing state of the biological environment on southern Roberts Bank in the general area to be considered for expansion of the present coal terminal (Westshore Terminals). It is based on a compilation of available literature and field studies conducted from April to June, 1977 by Beak Hinton Consultants, and builds on the physical base described in Appendix A. Because of the low cost effectiveness and because of the time of year the study was conducted, the field effort concentrated on the basic biological determinants - vegetation and benthos. New, specific studies of fish and wildlife would have required much more lengthy study at other times of the year to produce useful field results, and even then would have added little to the information already on hand.

We do not consider this lack to be serious, because other researchers have covered these higher animals fairly extensively. As well, physical environment information from Appendix A together with vegetation and benthic data provide a solid description of the habitat for fish and wildlife. We have made the conservative assumption that, if the habitat is there, it will be fully utilized unless proven otherwise. Thus, we assume any habitat alteration will cause a corresponding impact on fish and wildlife. Lengthy study of fish and wildlife should serve only to demonstrate the habitat is less than fully utilized, and therefore that the impact on fish and wildlife is less than we have described in the main report (Volume 2).

This appendix is subdivided into sections on emergent vegetation, submergent vegetation, benthos (including crabs), fish, avifauna, and other wildlife.

General Location Map

B2.0 EMERGENT VEGETATION OF ROBERTS BANK

This section discusses emergent vegetation, that of the salt marshes of Roberts Bank south of Canoe Pass.

B2.1 INTRODUCTION: PACIFIC COAST MARSH FLORA

Since Chapman's (1960) work on salt marshes of the world, which covers the west coast of North America only briefly, very little information has been published about floristics of west coast marshes, and even less involving their ecology. The northwest coast especially has been neglected.

Early work on marshes was concentrated along the southern Pacific Coast. Purer (1942) investigated the marshes and their associated environmental variables of San Diego County,. California. Of the species considered, only one occurs in the Pacific Northwest (*Distichlis spicata*). Vogl (1966) considered Upper Newport Bay in California which, while typical of southern marshes, includes some species which overlap with northern ones. *Salicornia virginica* proved to be an extremely tolerant species, surviving a wide range of environmental conditions, from wet saline to dry non-saline. *Spartina* occurs as a colonizer and *Salicornia* is scattered throughout Upper Newport Bay. Volg's observations indicated that only slight elevational change could result in marked vegetation changes.

Further north, Hinde (1954), working in San Francisco Bay, attempted to establish relationships between tide levels and species distribution but again the species involved included very few of the northern Pacific coast species.

MacDonald and Barbour (1974) have summarized the scant information available on Pacific coast marshes and discern three distinct

regions. The southermost section being Baja, California, where salt marshes grade into mangrove swamps. North of this is the central section, with great species diversity and a warm, dry Mediterranean type climate. This region sharply ends in the vicinity of Point Conception in northern California. The northermost region, comprising Alaska, B.C., Washington and Oregon, appears to be fairly uniform in its species distributions with many species consistently occurring in the same environmental niches over a wide range. *Carex lyngbyei*, *Salicornia virginica*, *Triglochin maritima*, *Scirpus americanus*, *Scirpus paludosus*, and *Distichlis stricta* occur as common elements throughout the area.

B2.2 THE FRASER RIVER FORESHORE MARSHES

Despite the Fraser River foreshore marshes being some of the most extensive in B.C., very little attention has been focused on them. MacDonald and Barbour (1974) dismissed them in a paragraph, stating "Descriptions of the Fraser River Delta Marshes (49^{o}N) have not been found in the literature" (p. 206). However, there are a number of local publications which do offer some information.

Gates (1967) in reviewing the status of wet land reserves in the Lower Mainland briefly described some of the more important marsh areas. Burgess (1970) as part of his masters thesis on duck habitat and food, developed generalizations with regard to marsh zonation as well as estimated seed production of the major species (*Scirpus americanus*, *Carex lyngbyei*, *Eleocharis macrostachya*, *Scirpus paludosus* and *Scirpus validus*). He concluded that plant species distribution was influenced by tidal flooding, degree of drainage and possibly salinity, although he did not investigate the last variable. *Carex lyngbyei*, *Scirpus validus* and *Scirpus americanus* were the most important marsh food sources for ducks.

Becker (1971) in summarizing information on ecological relationships in the Fraser River foreshore, relied mainly on Burgess' (1970)

vegetation information.

McLaren (1972) and Forbes (1972), whose works have been quoted extensively in recent literature, provided floral descriptions of the Fraser marshes. Wade (1972) briefly considered the distribution of plant species along the Sturgeon Bank region of the foreshore, and also included a floral list.

Harris and Taylor (1973) gave cursory mention to the vegetation of the marshes as related to migratory waterfowl use. Northcote (1974) considering mainly fisheries aspects in his review of the "Biology of the Lower Fraser", relied mainly on Forbes' (1972) and McLaren's (1972) maps to summarize vegetation distribution. In addition he concludes..."Probably they (marsh areas) form an important habitat for various invertebrates and young fishes, including salmonids" (p. 9).

An attempt was made by Hoos and Packman (1974) to synthesize all available environmental information on the Fraser River Estuary. Most of the floral information was again derived from Forbes (1972) and McLaren (1972) but also includes references to the relevant papers on algal distribution.

Yamanaka (1975) conducted the first detailed investigation into Fraser delta marsh productivity and found that three species, *Carex lyngbyei*, *Scirpus americanus* and *Scirpus paludosus* accounted for over 80 per cent of the standing crop. The average dry matter yield was 4.9 tons per hectare. Among his transects, one covered the Tsawwassen marsh, between the Westshore Terminal and the Tsawwassen Terminal. Major species in this area were *Distichlis stricta* and *Salicornia virginica* with minor components of *Atriplex patula*, *Grindelia integrifolia* and *Hordeum jubatum*. Dry matter yield in this area ranged from 209 - 341 g/m^2 as opposed to a range of 114 - 1179 g/m^2 in brackish marshes to the north of this area. The dry matter weight of the emergent vegetation

showed the general trend of decreasing with distance from the dyke and in addition diversity also increased seaward.

Hillaby and Barrett (1976) also conducted detailed investigations of the Tsawwassen marsh in order to describe existing plant communities. They conclude that *Salicornia validus* and *Distichlis stricta* are able to colonize mudflats and hence build up substrate enabling species such as *Grindelia integrifolia* and *Atriplex patula* to move in. Since Yamanaka (1975) reports *virginia* as the local *Salicorna* species this name will be used in this report.

Parsons (1975) analyzed a salt marsh community at Boundary Bay and discovered that small increases in elevation resulted in great changes in soil conductivity. Hence the plants lower in the intertidal zone were subject not only to longer periods of innundation but also higher soil salinities. The species at this site were quite comparable to those of the Tsawwassen marsh.

Ongoing work at present involves a detailed study into the brackish marshes of the Brunswick Point area: productivity, vital environmental factors and responses to transplantation (Moody, 1977).

Despite the amount of description which occurs on the Fraser marshes, maps depicting the area have been relatively inaccurate. Medley and Luternauer (1976), however, in mapping sediment distribution of the tidal flats produced very good quality maps delimiting the marsh boundaries.

Since very little work exists on the environmental factors controlling Fraser River foreshore marshes, it is advisable to consider similar marshes in Oregon which have been extensively studied.

Jefferson (1975) has drawn a simplified successional scheme based on information from six Oregon estuaries, collected by Johannessen (1961). In general, the pattern seems applicable to the Fraser area. Pioneer species may be *Triglochin maritima* and *Scirpus paludosus* on silt, or *Scirpus americanus* and *Salicornia virginica* on sand. *Carex lyngbyei* occurs as an intermediate in almost all cases. The mature high salt marsh is a mixed community of *Salicornia*, *Distichlis* and *Juncus*, provided no dyking or filling occurs.

Eilers (1975) developed a model which indicated that marsh development begins once the substrate has reached an elevation of 1.25 m above Mean Low Low Water. Initial precursors "filter" the water and result in increased sedimentation. Initial populations are monospecific due to the stress of long periods of submergence. These populations expand and eventually coalesce and accretion continues. Most of the vegetative material is exported from this region of the marsh. Litter does not contribute to the accretion rate until the marsh elevation approaches Mean High High Water when the litter combines with strand deposition and is incorporated into the substrate. Decomposition within the substrate is slow, as anoxic conditions prevail in the waterlogged soils. A break in slope occurs at this point, where the rapid accretion begins, soils become more aerated in the higher marsh and more terrestrial in nature. Since the high marsh is less exposed to tidal action little export occurs from this region into the estuarine system.

Ranwell (1972) and Chapman (1960) have noted that colonization of tidal flat areas occurs very slowly until a critical threshold is reached, after which colonization occurs very rapidly. Disruption of substrate conditions at this point could result in a lengthy delay in marsh colonization.

The critical factors involved in marsh development and growth appear to be as follows:

i) elevation in relation to sea level: associated factors include the amount of sedimentation which eventually determines the elevation of the tidal flat and the period of exposure and submergence for the vegetation, which is controlled both by the elevation and the tidal regime.

ii) nature of the substrate: whether sand or silt, and its water holding capacities.

iii) the salinity regime: which depends on tidal action, river influence and elevation.

Human impact on marshes, apart from the direct effects of ditching, dyking and filling, are greatest when the environmental variables controlling marsh development are altered. Hence, modification of tidal flow, sediment discharge and substrate disruption are probably of greatest importance to marsh systems.

B2.3 THE STATUS OF EMERGENT VEGETATION ON SOUTHERN ROBERTS BANK

B2.3.1 Tsawwassen Marsh

Boun

The area is characterized by the presence of a true salt marsh, entirely distinct from all other Fraser River estuarine marshes.

Aerial photographs taken in September, 1932 indicate that the shape of the marsh was much the same as it is today. However, the

areal extent at that date was approximately 94 hectares as opposed to the present 79. The leading edge of the marsh had a gentle slope and was fronted by a band of colonizing vegetation, probably *Salicornia virginica* and *Triglochin maritima*, the widest reach of which occurred in the northwest corner of the marsh. Vegetation composition on the whole appeared to be much the same in 1932 as in 1977. Drainage channels have remained remarkably stable over the past 45 years, thus providing excellent guidelines for asessing marsh changes.

Medley and Luternauer (1976) indicate the probable origin of the Tsawwassen marsh as being glacial deposits from Point Roberts, transported northward by longshore drift and filling in the upland embayment. If such is the case then the construction of the Tsawwassen Terminal resulted in the termination of the longshore drift, retreat of the leading edge of the marsh and the development of a steep slope.

Medley and Luternauer (1976) observed only minor retreats. Of the three sites of retreat observed, two were noticeable prior to Tsawwassen Terminal construction. There has been difficulty in interpreting the vegetation of the leading edge of the marsh, however, and retreat may be considerably greater than that estimated (Medley, pers. comm.).

Luternauer (1977) observed that an increase in grain size occurred with depth in the Tsawwassen marsh and attributed this to decreased wave energy and/or sand supply which may be a result of causeway construction (see Appendix A).

Pres

As of 1976, the Tsawwassen marsh occupied an area of approximately 79 hectares, indicating a retreat of 15 hectares in the past 44 years. Incomplete photo coverage hinders accurate mapping and measure-

ment, but available photography indicates that most of this retreat had occurred by 1963. Field checks indicate erosion is continuing at the marsh front as the dyke constructed in 1975 has yielded to wave and drainage channel action in two locations.

The vegetation is composed of varying mixtures of the same basic species, *Grindelia integrifolia*, *Distichlis stricta*, *Salicornia virginica*, and *Atriplen patula* with a few minor species (Figure B1). These exhibit a low yield, in the order of 209 - 341 g/m^2 of dry weight (Yamanaka, 1975) and, as tidal innundation is infrequent, there is little export to the marine system. This is evidenced by a greater standing stock of dead than live vegetation in one season (Yamanaka, 1975).

Interpretation of available photographs has indicated that a slow steady erosion of the marsh front has occurred, possibly due, in part, to the disruption of longshore drift caused by the Tsawwassen Terminal. The construction of the Westshore Terminal causeway does not seem to have accelerated erosion in this area, as evidenced in recent aerial photographs. The Westshore causeway construction has caused a rise in the elevation of the substrate adjacent to it. This in turn has permitted colonization by *Salicornia virginica* and *Triglochin maritima* to the south and north sides (of the causeway) respectively.

The newly colonized *Salicornia virginica* now occupies an area of close to 2 hectares while *Triglochin maritima* occupies approximately 3 hectares. The latter may have a larger area because of greater sedimentation rates in the north side due to the impounding of Fraser River water by the causeway and tidal action (see Appendix A). The time of initial plant establishment is not available since early records of vegetation along the causeway do not exist and photo interpretation is impossible due to the sparseness of early colonizing vegetation.

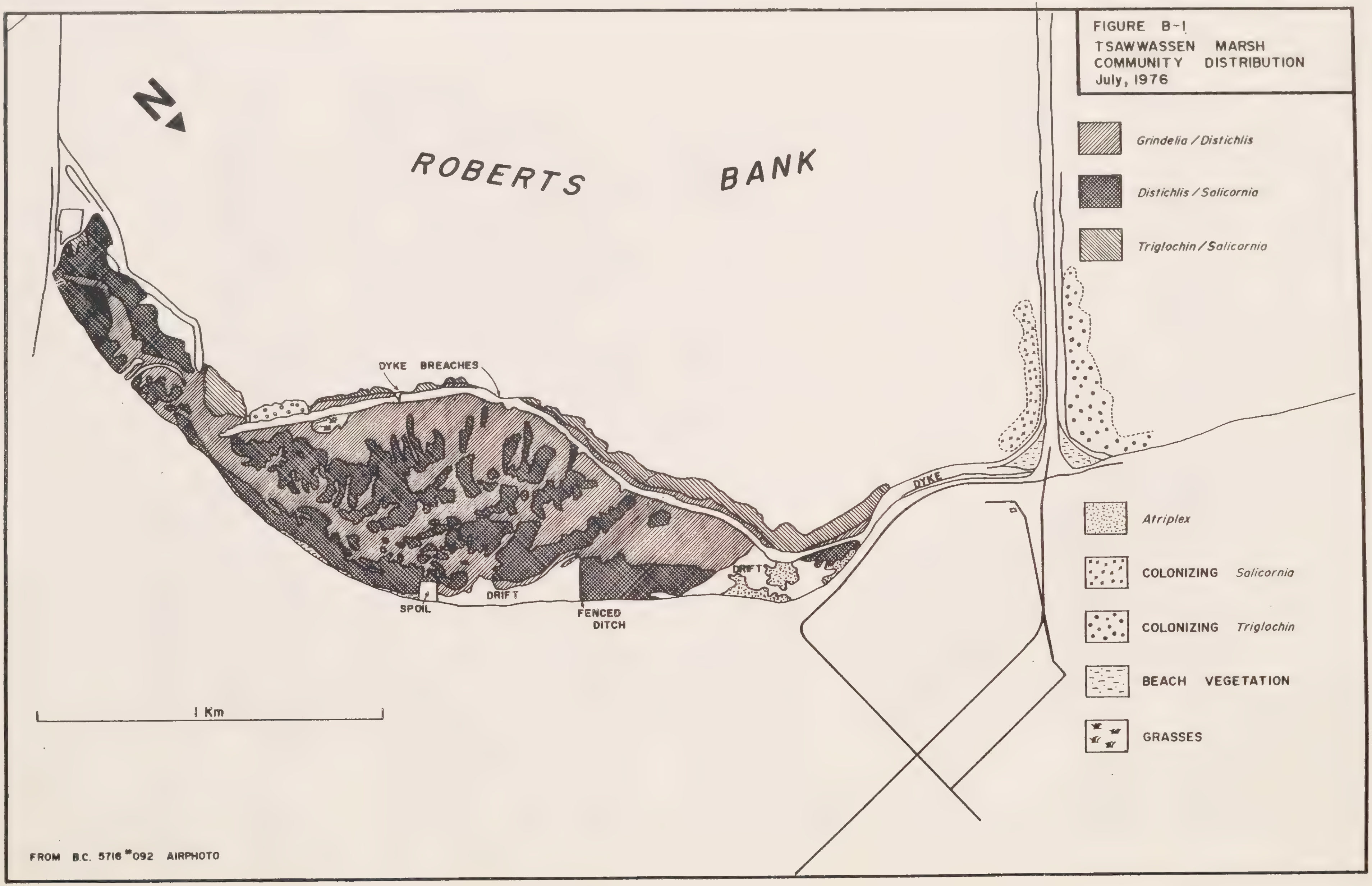


FIGURE B-1
TSAWWASSEN MARSH
COMMUNITY DISTRIBUTION
July, 1976
Grindelia / Distichlis
Distichlis / Salicornia
Triglochin / Salicornia
Atriplex
COLONIZING Salicornia
COLONIZING Triglochin
BEACH VEGETATION
GRASSES
N
ROBERTS BANK
DYKE BREACHES
DYKE
DRIFT
SPOIL
DRIFT
FENCED DITCH
1 Km
FROM B.C. 5716 #092 AIRPHOTO

B2.3.2 Brunswick Point Marsh

This marsh, lying to the north of Westshore Terminals is a brackish marsh, typical of the Fraser foreshore. Dominant species are *Carex lyngbyei*, *Scirpus paludosus* and *S. americanus* (Figure B2).

Air photos taken in 1932 indicate the extent of the marsh as 72 hectares, of which *Carex lyngbyei* occupied 21 hectares. By 1948 the marsh had extended in a southeasterly direction and despite agricultural expansion onto previous marsh, total area had increased by two hectares. It is interesting to note that, after dyke extension between 1938 and 1948, areas of *Carex lyngbyei* (typical of a high, fairly mature marsh) which had previously extended quite far to the southeast, retreated - probably as a response to decreased sedimentation and higher salinities resulting from river water diversion by the dykes (Moody, 1977).

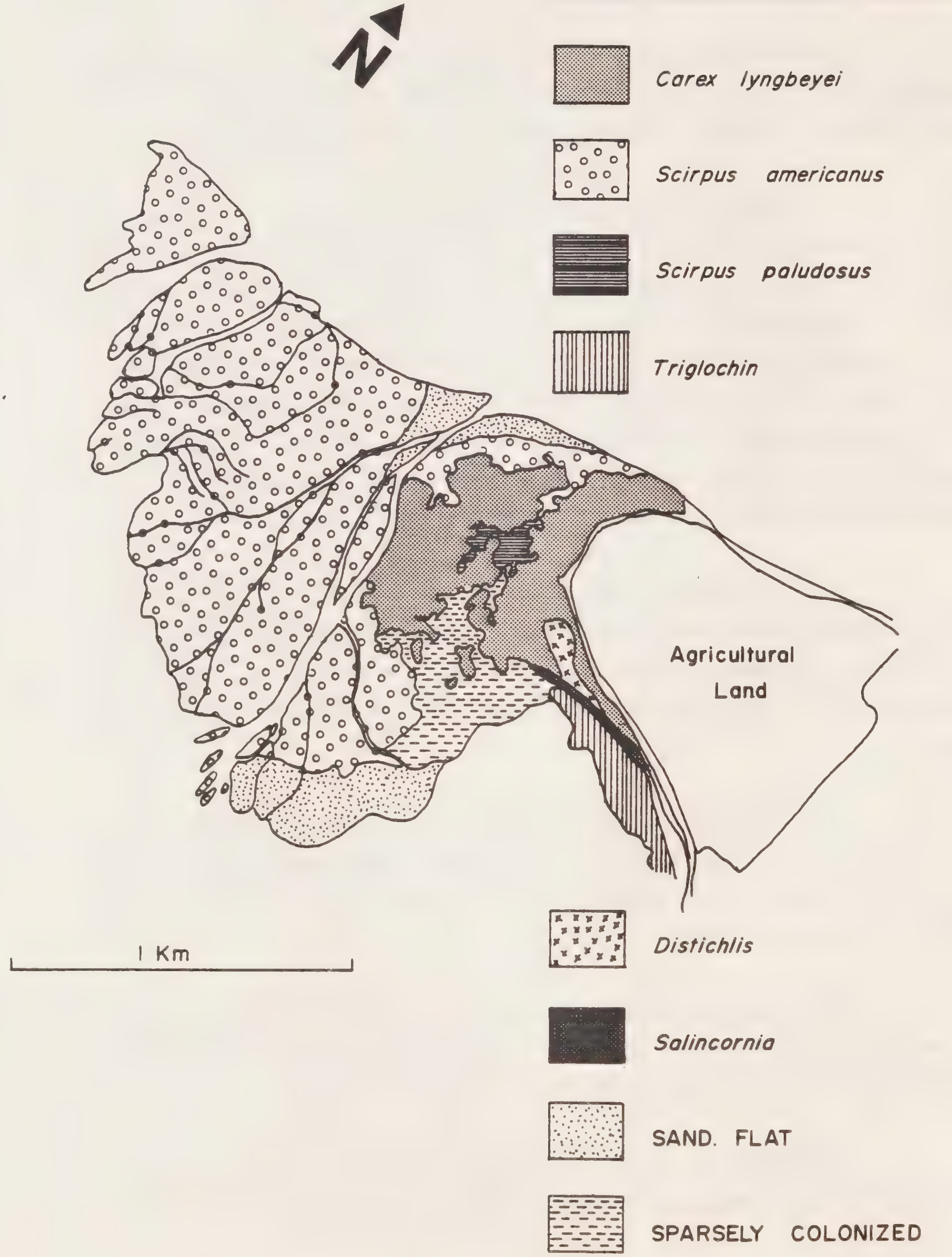
In 1948, large areas of raised sand flats were evident at the northwestern tip of the marsh, but without colonizing vegetation. By 1969 this expanse of sand flat was densely vegetated and occupied approximately 90 hectares in addition to the 1946 marsh area of 74 hectares.

The total extent of Brunswick Point marsh was about 170 hectares in 1976. The expansion of this area seems to have been brought about by a steady rise in sediments due to river deposition and subsequent plant colonization.

Productivity in this area is high, in the order of 1,000 g/m^2 per year (dry weight) most of which is exported to the estuary as marsh surfaces are cleared of dead vegetation by winter storms.

The Brunswick Point marsh appears to have undergone sporadic periods of rapid growth in the past 45 years, with only minor species

FIGURE B-2
BRUNSWICK MARSH
COMMUNITY DISTRIBUTION
June, 1975



changes within the marsh. This is to be expected according to previously described marsh colonization patterns (Ranwell, 1972; Chapman, 1960). At present, Brunswick Point marsh appears to be nearing another phase of rapid expansion to the south.

Marsh development does not appear to have been affected in any way by port facility or causeway construction as construction practices have not altered river or tidal flow patterns in the vicinity of the marsh. An impoundment of sediment laden water between the causeway and marsh may accelerate sediment deposition in the area and thus result in more rapid marsh colonization. This would not be the creation of new habitat but perhaps the acceleration of a natural process.

B2.4 EMERGENT VEGETATION SUMMARY

The emergent vegetation of southern Roberts Bank consists of two basic types; the brackish, highly productive Brunswick Point marsh near Canoe Pass and the Tsawwassen salt marsh of low yield to the south, between the two causeways. Different origins and environmental factors are responsible for these sharp distinctions.

Port and causeway development has had no perceptible effect on the Brunswick Point marsh. The key to its continued growth is the steady contribution of sediments by the river. Any development which would decrease or alter this flow would result in modification of the marsh. Presently, the impoundment of sediment laden water north of the Westshore Terminal may be accelerating the natural extension of the Brunswick Point marsh to the south.

The Tsawwassen marsh may have had its substrate source truncated by the Tsawwassen Terminal and this effect possibly was compounded by the construction of the Westshore Terminal. This marsh has been

undergoing a retreat from its 1932 extent. However, colonization is still occurring in pockets along the leading edge and along the Westshore Terminal causeway.

It should be noted, however, that marshes are dynamic systems and retreat or advance in a particular area is not necessarily indicative of the general state of the marsh.

B3.0 SUBMERGENT VEGETATION OF ROBERTS BANK

The submergent vegetation occupies the intertidal and subtidal zones. The dominant species in this area is *Zostera marina* (eelgrass). Eelgrass is a marine vascular plant or seagrass, and is the only macrophyte on the Pacific Coast of North America capable of colonizing soft substrates in the lower intertidal and upper subtidal zones. Because of its great importance to the fauna of the area, the study has concentrated on this species.

B3.1 PAST STUDIES

Past studies of eelgrass on southern Roberts Bank tend to be irregular and poorly supported. As a result, it is unclear whether conflicting reports indicate unreliable assessment or rapid change in the status of eelgrass. For example, in 1967 a usually reliable researcher described the southern portion of Roberts Bank as "characterized by extensive, barren mud flats (low water) and very shallow water. Aquatic vegetation here is almost totally lacking". By 1974, Hoos and Packman were stating "the entire foreshore exposed at low tide is covered with algae", and, in 1972, Forbes notes eelgrass on the Tsawwassen foreshore in the vicinity of the Tsawwassen ferry slip, the Roberts Bank Port Facility Causeway...", totalling about 389 hectares on Roberts Bank. Our study (1977) found eelgrass to cover 609.3 hectares on southern Roberts Bank, making it by far the most important macrophyte in the area.

B3.2 GENERAL CHARACTERISTICS OF WEST COAST EELGRASS

To date there have been three major investigations into the ecology of eelgrass on the West Coast of North America. Keller (1963)

investigated the growth and distribution of eelgrass in Humboldt Bay, California. He found that the optimum depth for eelgrass growth was -1.0 ft. (Mean Low Low Water). In 1972 McRoy presented a collection of essays concerning the biology of eelgrass in Alaska. He considered such diverse topics as taxonomy, growth, chemical composition, biogeography, nutrient cycling and population characteristics of eelgrass systems. In his doctoral dissertation "Ecological Life History of *Zostera marina* L. (Eelgrass) in Puget Sound, Washington" Phillips (1972) deals with eelgrass habitat and biology as well as describing the various plants and animals associated with eelgrass in Puget Sound.

B3.2.1 Biology

Eelgrass is a member of the Potamogetonaceae, subfamily Zosteroideae (den Hartog, 1970). It has two types of stems, a perennial vegetative stem that is a prostrate, rooting rhizome and an annual leafy photosynthetic stem that is an erect branch of a horizontal rhizome and is termed a turion. Eelgrass beds are perennial features although well defined annual cycles are apparent within the beds. Peak leaf productivity occurs from April to June in this area and peak biomass is reached in mid-July. Reproductive turion density reaches a maximum in June when 5% of the turions are flowering. In August leaf numbers, turion densities, and biomass are reduced and a steady decline occurs throughout the fall and winter. However, the decline is incomplete, for many of the plants persist over the winter.

B3.2.2 Habitat

Eelgrass is a eurythermal (0^{o} to 30^{o}C), euryhaline (10 to 40 $^{o}/oo$) species and is unable to tolerate exposure to wave shock. Moderate currents seem to enhance growth.

Two other habitat factors, substrate and light, require further elaboration. In Puget Sound, Phillips (1972) never observed eelgrass growing on pure sand. The eelgrass beds of Roberts Bank are unusual for the northwest in that they have colonized pure sand substrate. Phillips (1972) concluded that the lower limit of growth in Puget Sound was controlled by low light levels which exist at depth. Thus, less turbid water should result in deeper eelgrass beds, provided other habitat conditions are right.

B3.2.3 Importance

Thayer et al (1973) state "The true importance of seagrass meadows to coastal marine ecosystems is not fully understood and is generally underestimated" (p. 288). They summarize the ways that eelgrass acts to affect the function of estuarine ecosystems as follows:

1. Eelgrass has a high growth rate, producing on the average about 300 - 600 g dry weight/m^2/year, not including root production.
2. The leaves support large numbers of epiphytic organisms, with a total biomass perhaps approaching that of the grass itself.
3. Although a few organisms may feed directly on the eelgrass and several may graze, the epiphytes and major food chains are based on eelgrass detritus and its resident microbes.
4. The organic matter in the detritus and in decaying roots initiates sulphate reduction and maintains an active sulphur cycle.
5. The roots bind the sediments together, and, with the protection afforded by the leaves, surface erosion is reduced, thereby preserving the microbial flora of the sediment and the sediment-water interface.
6. The leaves retard currents and increase sedimentation of organic and inorganic materials around the plants.
7. Eelgrass absorbs phosphorus both through the leaves and the roots

and returns phosphate from the sediments to the water column. Nitrogen is also taken up by the roots and transferred to the leaves and into the medium.

Thus eelgrass meadows form extremely complex ecosystems which function chiefly through intricate detrital food webs.

The importance of eelgrass to invertebrate herbivores and detritivores is well documented (epifaunal studies: Kita and Harada (1962), Marsh (1971) and Winkler and Dawson (1963); benthic infauna: Burke and Mann (1974), Kikuchi (1966), Marshall (1947), Orth (1973) and Stauffer (1937)).

Outram (1957, 1961a, 1961b, 1974) mentions the importance of eelgrass as an attachment substrate for herring spawn in B.C. coastal waters. In the Strait of Georgia he found 34% of all herring spawn located deposited on eelgrass. Other relationships between fisheries and the eelgrass resource are described in Kikuchi (1966, 1974).

It is believed that the massive reductions in waterfowl populations (especially Black Brant) in the North Atlantic flyway during the early 1930's were directly attributable to the almost complete disappearance of eelgrass in that area a few years earlier (Cottam, 1934). The importance of eelgrass to waterfowl is described in the more recent works of Moffitt and Cottane (1941), Einarsen (1965) and Ranwell and Downing (1959).

B3.2.4 Sensitivity to Disturbance

In view of the position of eelgrass as the key element in many long and valuable food webs, the influences of various human activities on seagrass systems assume increasing importance. Only a few

human activities have been documented as being deleterious to seagrass communities and on this point conflicting results have been reported in the literature.

There is no information available on the effects of toxic pollutants on eelgrass. The ecological effects of dredging on seagrass beds in Texas have been studied by Odum (1963). During dredging, light penetration was much reduced and productivity of the grasses diminished. During the following growing season, in areas not covered by silt, plant production was greater than during the dredging and pre-dredging periods. The enhanced growth was attributed to redistribution of dredge spoil and possible increased availability of mineral nutrients.

After the removal or disappearance of eelgrass, changes which occur in the substrate often make subsequent re-colonization impossible (Wood, 1959; Rasmussen, 1973). For example, eelgrass has been unable to successfully recolonize a removal site (borrow pit) in the seven years since its excavation on Roberts Bank. Substrate alteration, per se, does not appear to be the single cause; rather the depth/light relationship (referenced above) seems to be a reason.

The catastrophic ecological consequence of a sudden and drastic naturally caused decline in eelgrass stocks in the North Atlantic have been well documented. Man's destruction of grass beds has produced similar effects. Taylor and Saloman (1968, in Thayer et al, 1973) estimated that the destruction of 1,100 metric tons of seagrass by burial and removal during dredging in Florida resulted in the immediate loss of approximately 1,800 tons of infauna. They also estimated that at least 73 tons of fishery products and 1,100 tons of macro-invertebrate infauna were lost annually as a result of the dredging.

B3.3 THE STATUS OF SUBMERGENT VEGETATION ON SOUTHERN ROBERTS BANK

The tidal and sand flats of the Fraser River Estuary would appear to be an unlikely habitat for luxuriant growth of intertidal macrophytes.

This is indeed the case for Sturgeon Bank and much of Roberts Bank. However, once sufficiently removed from the light-inhibiting influence of the murky Fraser River outflow, more favourable habitat conditions prevail and marine vascular plants and algae flourish.

Southern Roberts Bank is the only area of the Fraser River Estuary which supports extensive underwater meadows of the seagrass *Zostera marina* L. (eelgrass). Eelgrass is a member of the highly evolved seed plants and possesses the roots and rhizomes typical of many of these plants. These allow it to colonize soft substrate of sand and mud. As almost all marine algae are free floating or require firm substrates for attachment (lithophilic), their habitat seldom overlaps with seagrass habitat.

B3.3.1 Eelgrass Habitat and Distribution Factors

Habitat Factors:

Table B1 lists the range and optimum values of habitat factors associated with the vegetative growth of eelgrass. The habitat conditions of Southern Roberts Bank are close to the optimum conditions described with two notable exceptions.

Most of the eelgrass on Southern Roberts Bank is found on a sandy substratum. In nearby Puget Sound, Phillips (1972) never found eelgrass growing on sand and Stout (1976) similarly failed to observe eelgrass on pure sand in Netarts Bay, Oregon. On a world-wide basis, however, eelgrass does occur on sand. It appears that when all other conditions are favourable eelgrass can successfully colonize pure sand.

The depth range of eelgrass on Southern Roberts Bank is unusually narrow, extending only to -1 m (below MLLW). The presence of

TABLE B1. HABITAT FACTORS AFFECTING EELGRASS GROWTH

Temperature	
Range World-wide	0 - 40.5°C
Optimum World-wide	10 - 20°C
Southern Roberts Bank Range*	7.8 - 17.5°C
Salinity	
Range World-wide	Freshwater - 42 ‰
Optimum World-wide	10 - 30 ‰
Southern Roberts Bank Range*	13.8 - 30.0 ‰
Substrate	
Range World-wide	pure firm sand to pure soft mud
Optimum World-wide	mixed sand and mud
Southern Roberts Bank Range*	pure sand to mixed sand and mud
Wave Motion	
Range World-wide	waves to stagnant water
Optimum World-wide	little wave action, gentle currents
Southern Roberts Bank Range*	low wave shock, gentle currents
Depth	
Range World-wide	MLLW to -30 meters
Optimum Puget Sound	-1 to -4 meters
Southern Roberts Bank Range*	+1 meter to -1 meter

* Southern Roberts Bank information collected from April, 1976 to January, 1977 (R. Moody, 1977).

(modified from Stout, 1976)

uncolonized, but apparently suitable, substrate beyond the lower limit of eelgrass growth suggests that the lower limit is determined by light availability in the turbid estuarine waters.

Historical Distribution:

The eelgrass meadow of Southern Roberts Bank has been a persistent feature for many years. An oblique aerial photograph of the area taken during low tide on June 10, 1949 indicates that the eelgrass bed covered its present location at that time. Although no earlier historical references could be found it is safe to assume that the bed has been an established feature for a long time.

The Tsawwassen Ferry Causeway bisected the eelgrass bed in 1960. The vegetation map for 1966 indicates that the construction of the causeway and the dredging of a channel parallel to, and south of the causeway, had minimal effects on the eelgrass meadow. Aside from the removal of eelgrass habitat adjacent to both sides of the causeway, no other effects are apparent. Similarly, the presence of eelgrass to the very edge of the dredged channel, even several years after dredging, shows that the removal of habitat did not affect the surrounding vegetation. In July, 1966, 534.5 hectares were covered by eelgrass and macrophytic algae in the area north of the Tsawwassen Terminal (Figure B3).

Present Distribution:

A series of high altitude normal colour and colour infrared aerial photographs taken in June, 1975 during a particularly low tide is the best information available for mapping the present distribution of the vegetation.

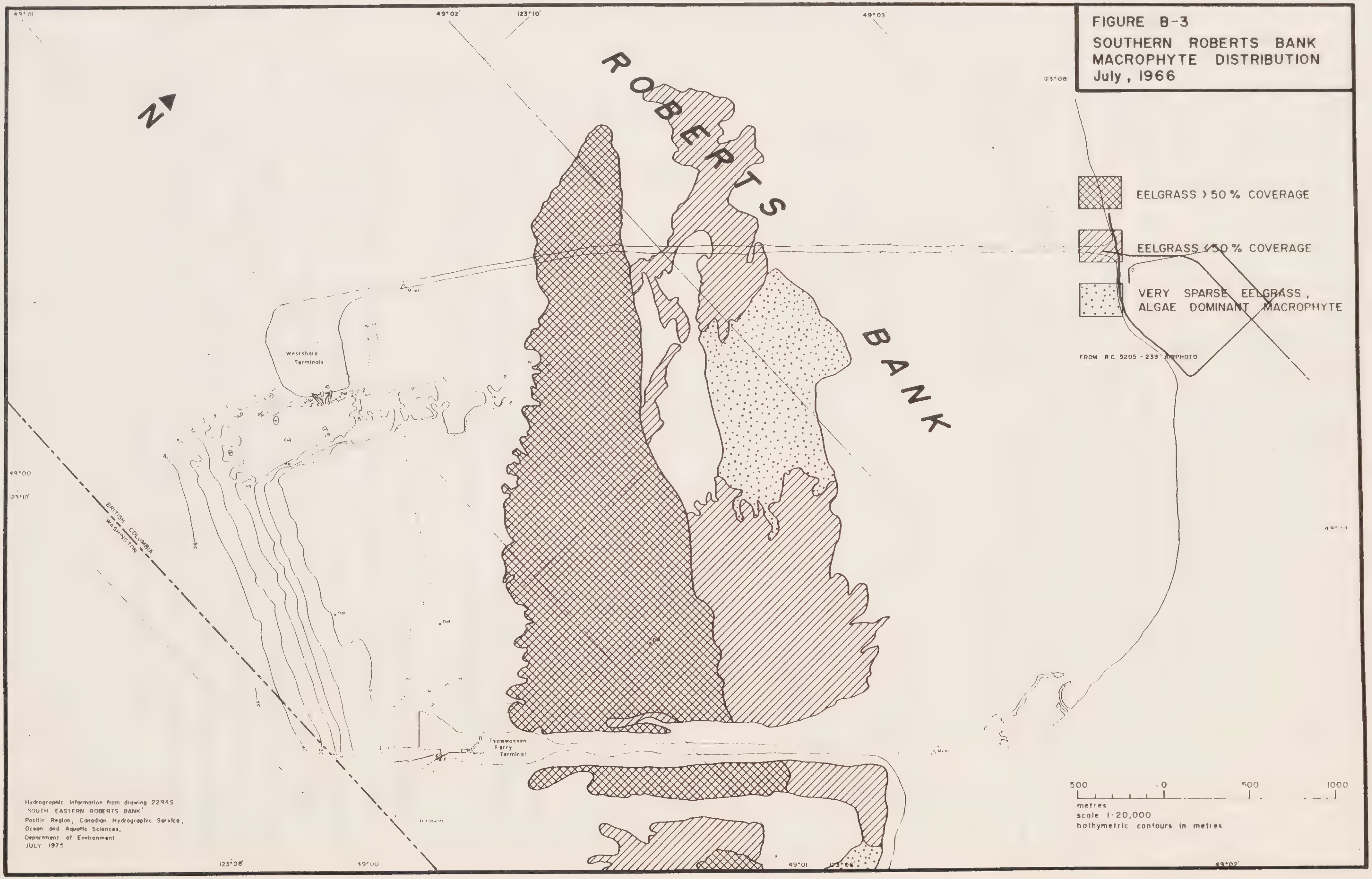


FIGURE B-3
SOUTHERN ROBERTS BANK
MACROPHYTE DISTRIBUTION
July, 1966
N
ROBERTS BANK
EELGRASS > 50 % COVERAGE
EELGRASS < 50 % COVERAGE
VERY SPARSE EELGRASS, ALGAE DOMINANT MACROPHYTE
FROM BC 5205 - 239 AIRPHOTO
Westshore Terminals
Tsawwassen Ferry Terminal
BRITISH COLUMBIA
WASHINGTON
500 0 500 1000
metres
scale 1:20,000
bathymetric contours in metres
Hydrographic Information from drawing 2294S 'SOUTH EASTERN ROBERTS BANK' Pacific Region, Canadian Hydrographic Service, Ocean and Aquatic Sciences, Department of Environment JULY 1975

The construction of Westshore causeway appears to have had several effects on the eelgrass meadow. The 1975 vegetation map shows a denuded zone on either side of the causeway (Figure B4). The edges of this zone coincide with the lateral boundaries of the dredge spoil as it was being deposited. Field reconnaissance showed that the area of former eelgrass habitat has been raised above the upper depth limit of eelgrass growth. The direct effects of causeway construction on the eelgrass meadow have been restricted to those areas removed as eelgrass habitat by the raising of substrate levels.

Dredging activities associated with causeway construction have had an additional effect on eelgrass distribution. Much of the dredged material used in the construction of the causeway was obtained from a borrow site which was established within the eelgrass meadow. The original borrow pit, located at the end of the ship channel to the south of the Westshore Terminal facility, covered an area of 8.0 hectares (Table B2). Field observations in May, 1977 revealed that the borrow pit has retained its original size, shape and depth configuration. Slopes on the order of 45° were observed bordering the borrow pit.

Air photos taken only a few months after the excavation was completed show a devegetated zone surrounding the perimeter of the borrow pit. This zone is still increasing in area and recent photos (July, 1976) reveal that the denuded area (including the pit) is now 2.5 times the area of the original pit.

The alteration of water drainage patterns across the eelgrass meadow during ebb tides (see Appendix A, section A4.2) appears to explain the presence and expansion of the devegetated areas. Before the excavation of the borrow pit, the ebbing tide flowed over a broad vegetation front seaward and in a northwesterly direction along the shoreward edge of the eelgrass meadow. The northern flow has been cut off by the causeway, and the dredged channel provides a convenient drain. Very high

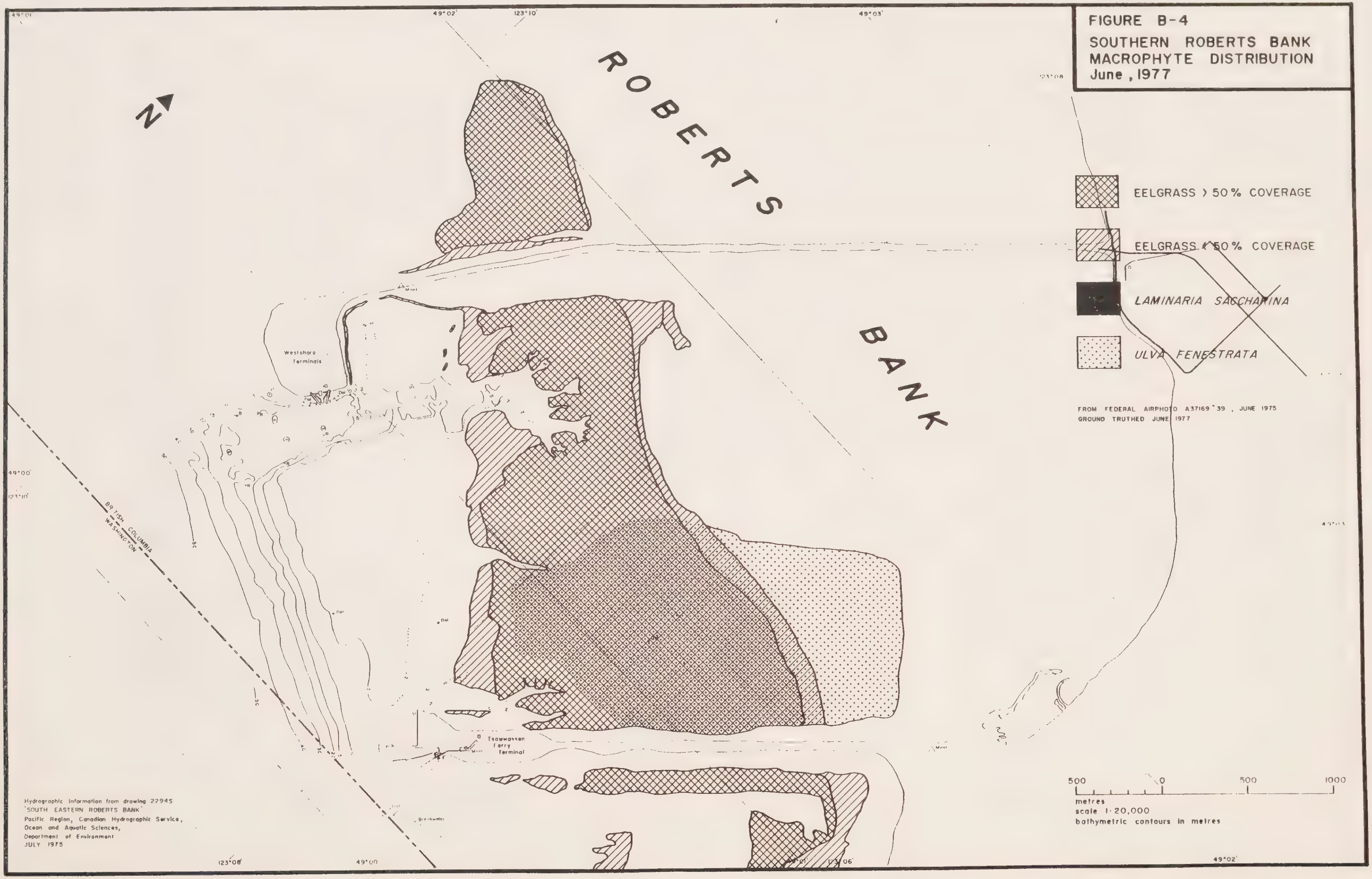


FIGURE B-4
SOUTHERN ROBERTS BANK
MACROPHYTE DISTRIBUTION
June, 1977

TABLE B2. DEVEGETATING EFFECTS OF BORROW PIT ESTABLISHMENT WITHIN THE INTERCAUSEWAY EELGRASS MEADOW

Date	Impacted Area (ha.)[1]	Airphoto
July 1969	3.5	BC 5351 #189
May 1970	4.3	BC 5371 #108
August 1971	6.7	BC 5431 #218
June 1974	8.0[2]	BC 5591 #131
July 1976	11.6	BC 5716 #027

1 Devegetated area excluding borrow pit area. Borrow pit area remained a constant 8 ha between March 1969 and May 1977

2 Boundaries partially extrapolated due to high water levels

water velocities were observed in these broad, shallow, recently created drainage channels. These drainage channels resemble wide, fast flowing creeks with high loads of sand. Although these high velocities (3 to 4 m/s estimated) are reached for only short periods of time and only during specific times of the year, they appear sufficient to scour any plants trying to colonize the bare areas. Note that this scouring is not necessarily serious in the engineering sense of large-scale bed movement, but the movement is sufficient to prevent plants rooting properly.

It is expected that the devegetated areas will continue to expand shoreward, at least until the eelgrass bed is breached. At that time one of the channels may capture most of the ebb discharge, thereby allowing other denuded areas to be successfully recolonized by eelgrass.

The changes in eelgrass distribution which have occurred since construction of the Westshore causeway are summarized in Table B3, and may be better illustrated by comparing Figures B3 and B4.

Specifically, total eelgrass coverage north of the ferry causeway (to Canoe Pass) was reduced 25% from 534.3 ha to 402.6 ha. However, nearly all of this reduction occurred in discontinuous eelgrass areas, while continuous eelgrass completed the colonization of the discontinuous area. Thus, continuous eelgrass area increased 21% from 276.8 ha to 336.3 ha during the same period.

Comparing Figures B3 and B4, it is apparent the causeway obliterated a large discontinuous area and some continuous area. The drainage erosion has eaten into significant continuous eelgrass. Counting this, continuous eelgrass has occupied nearly all the formerly discontinuous area near the ferry terminal. As well, a distinct seaward colonization is evident along the entire delta front between the cause-

TABLE B3. AREAL EXTENT OF SUBMERGENT VEGETATION, JULY 1966 and JUNE 1975

Area, Date	Continuous Cover (eelgrass)	Discontinuous eelgrass and algae (largely *Ulva lactuta*)
North of Ferry Causeway, 1966	276.8 ha	257.5 ha
North of Ferry Causeway, 1975	336.3 ha	66.3 ha
South of Ferry Causeway, 1966	26.6 ha	41.4 ha
South of Ferry Causeway, 1975	56 ha	18 ha

ways. This advance is probably due to increased light penetration to depth as a result of reduced Fraser River turbid water flow over the area and to greater wave protection.

Air photos taken since the construction of the causeway reveal a slow, but constant, shoreward extension of the upper limit of eelgrass growth. This advancement, at the approximate rate of 25 m per year, is speculated to be in response to changes in water circulation characteristics. The Westshore causeway has blocked part of the direction in which the ebb tide flowed and a damming effect is experienced as the tide ebbs over the eelgrass bed. This increases the duration of tidal inundation of the area between the eelgrass and the shoreline. As the upper limit of eelgrass growth is governed by tidal exposure (Keller and Harris, 1966) the net result has been a shoreward extension of the eelgrass bed. On Southern Roberts Bank, eelgrass is not found above the zone which is exposed for more than 1% of the time (Moody, 1977). In the area south of the Tsawwassen Ferry Terminal Causeway, the 1% exposure line coincides with the +0.81 m elevation contour and +1.0 in the intercauseway area.

Acknowledging the relative eelgrass densities, there is no evidence to suggest there has been any net loss of eelgrass as a result of construction of Westshore causeway. Indeed, as the eelgrass is still expanding its territory in reaction to its habitat alteration, there may be a net gain in eelgrass area in the near future as a result of the Westshore causeway.

B3.3.2 Eelgrass Field Studies

The eelgrass meadow of Southern Roberts Bank has been divided into three sections by the construction of two causeways across the eelgrass bed. Field studies were initiated to investigate various popu-

lation characteristics of the three sections to determine the effects of construction, development and habitat alteration on eelgrass growth. The characteristics investigated included turion densities (vegetative and reproductive), leaf measurements and biomass.

Turion Dendritus

The growth habit of eelgrass involves a horizontal rhizome from which erect leafy branches, called turions, arise. Turions within a 0.25 m^2 quadrat were counted. Results are expressed on per square metre basis.

Turion vegetative densities were determined for the May and June, 1977 samplings in three areas. Area N is north of the Westshore Terminal, S is south of the Tsawwassen Terminal, and M is between the two causeways. Station designations are prefixed with the area letter (Figure B5).

Turion densities were higher in area M than in the other areas sampled (Table B4). Station MB showed little change in turion density between May and June 1977. Station N was similar when vegetative and reproductive turions are summed for June. The observed turion densities are low compared to other areas on the Pacific Coast (Table B5) (McRoy, 1972; Phillips, 1972: Stout, 1976).

Reproductive turion density provides an estimate of the sexual reproductive capacity of an eelgrass bed. The relationships between vegetative propagation and sexual reproduction in eelgrass are very poorly understood.

FIGURE B-5
MACROPHYTE SAMPLING STATION LOCATIONS

TABLE B4. MEAN AND STANDARD DEVIATION ($\overline{x} \pm$ S.D.) OF VEGETATIVE TURION DENSITIES (TURIONS/m^2), MAY AND JUNE, 1977

Station	May			June		
	$\overline{x}$	$\pm$	S.D.	$\overline{x}$	$\pm$	S.D.
N	81.3		14.5	66.8		42.2
MA	64.7		22.1	*		*
MB	194.0		19.6	204.0		14.2
MC	*		*	191.0		50.0
MD	*		*	109.0		64.1
SA	70		22.3	*		*
SB	*		*	150.0		28.8

* not sampled

TABLE B5. COMPARISONS OF EELGRASS TURION DENSITIES ON THE PACIFIC COAST

Location	Turions/m^2	Source
Sawmill Bay, Alaska	599	McRay, 1972
Izembek Lagoon, Alaska	4576	McRay, 1972
Bush Point, Washington	367	Phillips, 1972
Alki Point, Washington	468.69	Phillips, 1972
Netarts Bay, Oregon (shallow)	671	Stout, 1976
Netarts Bay, Oregon (deep)	1056	Stout, 1976
Southern Roberts Bank, British Columbia	70-204	Beak Hinton, 1977

In May no reproductive turions were collected during the samplings. Table B6 shows the number of reproductive turions observed as a percentage of the total number of turions counted at each station. An interesting pattern emerges when the station elevation is related to the percentage of reproductive turions observed. A direct relationship of elevation to reproductive turion density is apparent. Phillips (1972) has described a similar relationship and similar reproductive turion densities in Puget Sound.

TABLE B6. <u>REPRODUCTIVE TURION DENSITIES, JUNE 1977</u>

Station	Elevation	Total Turions	Reproductive Turions	% Reproductive
N	+.61 m	85	5	5.9
MB	0 m	204	0	0
MC	+.61 m	204	13	6.4
MA	+1.0 m	141	11	7.8
S	.3 m	150	0	0

Leaf length and leaf width were measured for the oldest intact leaf on each turion of several samples. There appeared to be little difference in leaf length or leaf width between the three areas described. Data contained in any habitat differences which may exist between the three areas have not been expressed in the vegetative characteristics of leaf length and leaf width.

TABLE B7. EELGRASS LEAF MEASUREMENTS ($\bar{x} \pm$ S.D. = MEAN $\pm$ STANDARD DEVIATION)

Station	Length (cm) $\bar{x} \pm$ S.D.	Width (cm) $\bar{x} \pm$ S.D.
N	49.7 ± 24.8	0.76 ± 0.16
MA	49.1 ± 24.9	0.57 ± 0.12
MB	50.6 ± 23.9	0.58 ± 0.16
S	39.9 ± 18.3	0.69 ± 0.15

Biomass:

Specific sampling locations were selected at random (Station 5, Figure B5) and the above ground parts within a 0.25 m^2 (0.5 m x 0.5 m) quadrat were harvested during May and June 1977. Following month's samples at identical stations were taken from adjacent quadrats. The samples were counted, cleaned of adhering epiphytes, and spun for two minutes in a centrifuge to ensure consistency during wet weight determinations. Samples were dried for 24 hours at 105°C and cooled in a dessicator before weighing. Subsamples were ashed at 550°C and ash-free dry weights determined by difference. Table B8 refers to ash-free dry weight (in grams) per square meter.

The patchy horizontal distribution of eelgrass plants within an eelgrass bed leads to difficulties in sampling as well as making the task of data interpretation quite complex. However, several general trends may be discerned from the biomass information collected. The area between the two causeways does not appear to have higher leaf biomass than the areas north and south of it. However, noting the magnitude of the variation of results (standard deviation percent of mean), it is likely that with elevation considered, the intercauseway area supports a higher density of eelgrass per given area.

TABLE B8. EELGRASS LEAF BIOMASS IN GM/M^2 ($\bar{x} \pm$ S.D. = MEAN $\pm$ STANDARD DEVIATION)

	May		June	
Station	Dry Weight $\bar{x} \pm$ S.D.	Ash Free Dry Weight* $\bar{x} \pm$ S.D.	Dry Weight $\bar{x} \pm$ S.D.	Ash Free Dry Weight* $\bar{x} \pm$ S.D.
N	34.8 ± 5.0	31.7 ± 4.5	107.9 ± 53.7	98.5 ± 49.0
MA	29.2 ± 9.8	26.6 ± 9.0	-	-
MB	99.5 ± 12.8	90.8 ± 11.7	130.8 ± 8.9	119.3 ± 8.1
MC	-	-	39.3 ± 6.3	35.9 ± 5.8
MD	-	-	85.5 ± 27.3	78.1 ± 24.9
SA	43.5 ± 8.6	39.7 ± 7.8	-	-
SB	-	-	137.9 ± 41.2	125.9 ± 37.6

* calculated on basis of 8.7% Mean Ash Content

The locations which were sampled on two occasions exhibited increases in biomass on the second sampling. As indicated earlier, there was little change in turion densities between samplings in these areas, consequently the increased leaf biomass originates in the plants that were there earlier and not from new shoots or turions.

At this time of year the above ground biomass is approximately twice as great as the below ground material (Moody, 1977). Taking the June dry weight data (Table B8) and adding 50% to the reported values gives a June standing crop estimate from 59 to 207 g/m^2. Peak biomass is reached in mid-July (Moody, 1977) so these figures are underestimates of the true peak standing crop of eelgrass on Southern Roberts Bank. Compared to other West Coast areas these figures fall within the ranges observed elsewhere (Stout, 1976) and the eelgrass of Southern Roberts Bank exhibits moderate productivity (Phillips, 1972)(Table B9).

TABLE B9. COMPARISON OF STANDING STOCK OF EELGRASS IN VARIOUS GEOGRAPHIC LOCATIONS DURING THE GROWING SEASON

Location	Standing Crop (Dry Weight in g/m^2)
Denmark	
Danish Coast	272 - 960
Macra Strand	210 - 487
Japan	
Kasaoka Bay	70 - 235
England	
Essex County	120
USSR	
White Sea	164 - 203
Sakhalin	31 - 895
Black Sea	100 - 150
United States	
Alaska	
Izembek Bay	186 - 324
Massachusetts	
Great Pond	5 - 29
New York	
South Nassau County, Long Island Sound	148 - 2470
California	
South Bay, Humboldt Bay	12 - 421
Arcartia Bay, Humboldt Bay	6 - 192
Washington	
Puget Sound	18 - 396
Roberts Bank	59 - 207

(after Phillips, 1972)

B3.3.3 Discussion of Eelgrass Results

The results of the field studies indicate that observed habitat differences between the three areas may influence certain population characteristics of the eelgrass in each of the areas. The area between the causeways and the area south of the Tsawwassen Terminal generally have more saline waters than the area north of the Westshore Causeway (Appendix A). This difference is on the order of 3 to 4 $^{0}/oo$ generally (Moody, 1977). Much of the time these more saline areas also experience greater water clarity (personal field observations, ERTS-1 satellite photos, Appendix A). However, the inter-causeway area has a muddier substrate compared to the substrate conditions found to the south of the Tsawwassen Terminal (personal observations). Further, wave action (Appendix A) is lower in the inter-causeway area than the areas immediately outside.

For these reasons the habitat conditions of the inter-causeway area appear to be the more favourable for eelgrass growth (CF. Table B1), thus, the relatively high turion densities and standing crop of the area.

The net productivity of eelgrass (in g/m^2) in nearby Puget Sound exceeds the values obtained for most of the worlds' cultivated crops (Table B10) (Phillips, 1972), and the eelgrass beds of Southern Roberts Bank are comparable, although lower in productivity than those of Puget Sound.

B3.3.4 Other Vegetation Distribution and Habitat

The benthic algal flora of Southern Roberts Bank is somewhat impoverished due to the lack of suitable substrate conditions. A notable

TABLE B10. COMPARISON OF NET PRODUCTIVITY OF CULTIVATED CROPS AND TWO MARINE SYSTEMS* (from Phillips, 1972)

Crop	Net Productivity (g/m^2) Per Year	Net Productivity (g/m^2) Per Day
Wheat, world average	344	0.94
Oats, world average	359	0.98
Corn, world average	412	1.13
Rice, world average	497	1.36
Hay, U.S. average	420	1.15
Sugar Cane, world average	1,725	4.73
Tall Grass Prairies, Wyoming	446	1.22
Short Grass Prairies, Wyoming	69	0.19
Seaweed Beds, Nova Scotia	358	0.98
Eelgrass (*Zostera marina*)		
Puget Sound	581	1.59
Denmark (Grøntved, 1958)	277	0.83

* All data except for eelgrass taken from data reported by Odum (1959)

exception is the presence of a large bed of *Ulva lactuca*, a free floating macrophyte, between the two causeways. This alga is found from the mid-intertidal (well above the eelgrass zone) down to the lower limit of eelgrass growth and partially overlaps the eelgrass in the lower intertidal zone. *Enteromorpha intestinalis* was found covering the rocks along the beach between the two causeways, and *Enteromorpha clathrata* was common on the sand flats of the upper intertidal zone. *Fucus* spp. is common in the lower intertidal zone on the rocks and rip rap around the Westshore Terminal. Two other macrophytes, *Sargassum muticum* and *Laminaria saccharina*, exist on Southern Roberts Bank because man has provided them with suitable substrates. Two rock piles and a section of discarded dredge pipe near the outlet of the borrow pit are covered with these algae. This supports the contention that macrophytic algae are scarce in the area because of a lack of suitable substrates for attachment. The distribution of concentrations of other vegetation is also plotted in Figure B4.

B3.3.5 Other Vegetation Field Studies

In addition to field verification for areal extent mapping, samples of *Ulva lactuca* were collected May 7, 1977 at Station MA. Biomass from these samples was determined as previously described. Table B11 presents the results of this analysis.

TABLE B11. *Ulva* BIOMASS, g/m^2 ($\bar{x} \pm$ S.D.), AT STATION MA, MAY 7, 1977

Wet weight	1008.5 ± 95.9
Dry weight	112.7 ± 16.6
Ash-free dry weight	78.9 ± 11.6

Ash content equalled 30% of dry weight.

On a per square metre basis the standing crop of *Ulva lactuca* approached that of eelgrass in this area.

B3.4 SUBMERGENT VEGETATION SUMMARY

In terms of areal coverage and standing crop, *Zostera marina* L. (eelgrass) is the dominant benthic macrophyte of Southern Roberts Bank.

The habitat conditions of Southern Roberts Bank approach the worldwide optima for eelgrass growth with two exceptions, suboptimal substrate and low light levels (turbidity) which restrict an eelgrass depth distribution to between -1 m and +1 m relative to MLW.

The eelgrass meadow of Southern Roberts Bank is a persistant feature which had experienced little net disruption in being disected by two causeways and a (major) dredge channel.

The use of eelgrass meadows as sources of fill material may have unsuspected long term effects which are detrimental to the surrounding vegetation.

Biomass values and turion densities are higher in the area between the causeways than in the neighbouring areas.

On the whole the eelgrass beds of Southern Roberts Bank are moderately productive compared to other West Coast eelgrass beds.

B4.0 BENTHOS

The only commercial species in the benthos of Southern Roberts Bank is Dungeness Crab. Accordingly, the description of this species has been segregated into a special section (B4.4) which follows the general discourse on the benthos.

Because of the nature of benthic studies, parts of this section are likely to be difficult technical reading for the layman and provide limited illumination. There is no better way to present these detailed sampling data, and our usual rule of writing for the layman has had to be partly abandoned.

B4.1 LITERATURE REVIEW

Although the lower Fraser River has been studied in some detail, (see Hoos and Packman, 1974 and Northcote et al, 1976 for reviews), the investigation of the benthos of Roberts Bank, and southern Roberts Bank in particular, have been few in number. The only quantitative samplings reported are those of Bawden et al (1973), Levings and Coustalin (1975) and McGreer (1975).

Bawden et al (1973) used a box corer, sampling to depths of from 6 to 28 cm for "Macrofaunal" samples. Microfaunal samples were collected with a glass tube pushed to 8 cm into substrate. Macrofaunal samples were seined with a 0.4 cm mesh and microfaunal with a nylon mesh of unspecified size. As a function of sampling method, the macrofaunal results were biased toward larger and deeper dwelling forms. Microfaunal samples were only reported to a limited number of higher taxa (nematodes, oligochaetes and harpacticoids).

The work of Levings and Coustalin (1975) involved two lines of transects and the southern portion of a perimeter transect in Southern Roberts Bank. Samples were intertidal and collections consisted of the uppermost 2 cm of sediment in a 0.06 m^2 or 0.25 m^2 quadrat. Samples were seived through a 0.5 mm screen prior to identification and enumeration. Data on taxa present, biomass and sediment composition were presented.

McGreer (1975) conducted a preliminary survey of physical, chemical and biological features of sediment to assess effects of buried power cables on marine intertidal fauna. The cables are located to the immediate north of the Tsawwassen Terminal, parallel to the causeway. Samples were collected with a corer to 25 cm and also by scraping the uppermost 5.0 cm of a 0.0625 m^2 quadrat. Samples were seived through both 1.0 and 0.25 mm mesh. Taxa present and sediment composition were reported.

B4.2 FIELD STUDIES

The field studies consisted of three inter-related aspects. The first was investigation of intertidal benthos and was designed to parallel the earlier work conducted as part of the proposed Vancouver International Airport expansion environmental impact assessment study. The second was a subtidal extension of the first. The third was a qualitative appraisal by direct observation, rather than quantitative sampling as above, using SCUBA apparatus.

B4.2.1 Materials and Methods

Materials and methods employed are discussed separately for each aspect of the study.

Intertidal Benthos:

Intertidal stations were sampled by removing all sediment in a 30.5 cm square quadrat (0.093 m^2) to a depth of 2 cm. Station elevations were calculated from Swan Wooster (1967) data (Table B12). All sampling took place between mid-April and early July, specific times are noted in the results.

TABLE B12. INTERTIDAL STATION ELEVATIONS

Station	Elevation (metres above LLW)
A1, B1, C1	2.5
A2, B2, C2	2.0
A3, B3, C3	1.5
A4, B4	1.0
A5, B5	0.5

Locations are shown in Figure B6. The "A" line was located approximately 50 m offshore of the northwest shore of the Westshore causeway, "B" line was 50 m off the southeast shore, "C" line was midway between the Westshore Terminal and the Tsawwassen Terminal (approximately 1.5 km southeast of the Westshore Terminal). Positioning was done with a Sesler hand bearing compass and locations post-plotted.

Duplicate samples were taken at each station and preserved with 5% buffered formalin. Rose Bengal stain was added to facilitate sorting. One of the quadrat samples was analyzed; the other being retained for possible future detail. Additionally, at each station, 0.5 - 1.0 kg of substrate was removed from the uppermost 10 cm for grain size analysis, temperature was taken at 3 cm depth in the substrate, and 0.5 l of water collected from the grain size sample hole for salinity analysis.

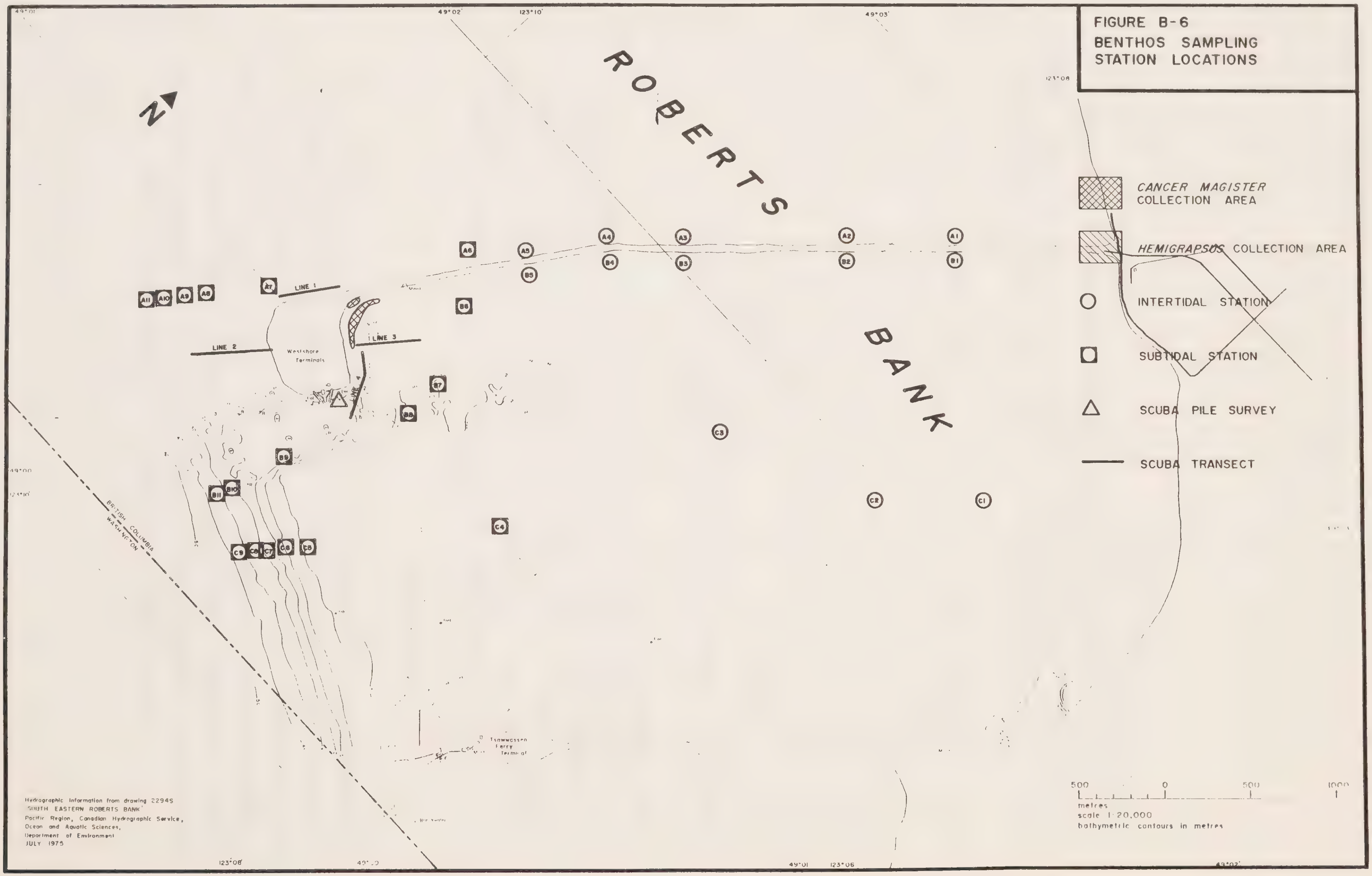


FIGURE B-6
BENTHOS SAMPLING
STATION LOCATIONS
CANCER MAGISTER COLLECTION AREA
HEMIGRAPSUS COLLECTION AREA
INTERTIDAL STATION
SUBTIDAL STATION
SCUBA PILE SURVEY
SCUBA TRANSECT
ROBERTS BANK
N
LINE 1
LINE 2
LINE 3
LINE 4
Westshore Terminals
Tsawwassen Ferry Terminal
BRITISH COLUMBIA
WASHINGTON
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
C1
C2
C3
C4
C5
C6
C7
C8
C9
49°01'
49°02'
49°03'
123°10'
123°08'
123°06'
49°00'
500
0
500
1000
metres
scale 1:20,000
bathymetric contours in metres
Hydrographic information from drawing 2294S
'SOUTH EASTERN ROBERTS BANK'
Pacific Region, Canadian Hydrographic Service,
Ocean and Aquatic Sciences,
Department of Environment
JULY 1975

Benthic macroinvertebrates were identified and enumerated according to standard taxonomic keys. References employed are contained in the literature cited section. After identification, the molluscs from each station were removed, shells dissolved in 10% HCl and the soft part returned to the original sample. The sample was then placed on 40 Whatman filter paper and the excess preservative vacuum filtered. The sample was then removed from the paper and weighed.

Subtidal Benthos:

Eighteen subtidal stations were sampled in quadruplicate with a ponar grab. Lines A and C were direct continuations of the intertidal transects. Line B angled to the south to cross the "borrow pit" and docking areas. Positioning was done with a Sesler handbearing compass and a Lowrance W-660 fathometer. Locations on Figure B6 are post-plots. Depths relative to LLW are given in Table B13.

TABLE B13. SUBTIDAL STATION DEPTHS IN METRES (FT) BELOW LLW

Station	Depth
A6, B6, C4	0.0 (0)
A7, B7, C5	4.6 (15)
A8, B8, C6	12.2 (40)
A9, B9, C7	19.8 (65)
A10, B10, C8	27.4 (90)
A11, B11, C9	36.6 (120)

Three of the replicates were seived in the field with 0.5 mm mesh prior to preservation. The fourth was retained for grain size analyses. Once returned to the laboratory, sample processing was the same as for the intertidal samples.

SCUBA Transects:

Four SCUBA transects were successfully swum in the vicinity of the existing Westshore Terminal. A vertical transect along some of the loading area piles was also swum. Figure B6 shows transect locations. These transects were designed to qualitatively assess the effect of the terminal and borrow pit on the biota of the outer bank. Underwater photographs were taken to supplement field notes.

B4.2.2 <u>Results</u>

Intertidal Benthos:

Detailed intertidal results are in Annex B1. Tabular summaries of statistics and grain size analyses are in Tables B14 and B15 respectively. Diversity (-d) was calculated with the Shannon-Weaver function (Lloyd <u>et al</u>, 1968):

$$-d = \sum_{=1}^{s} \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right) \qquad (1)$$

where: s = number of species
n_i = number of individuals of the i^{th} species
N = total number of individuals

Equitability (J), the eveness with which individuals are distributed among sampled species, was calculated according to Pielow (1966):

$$J = \frac{-d}{\log_2} \qquad (2)$$

Richness (R), an indicator of the relative "wealth" of species encountered without considering the number of individuals per species, was calculated according to Margalef (1958):

TABLE B14. INTERTIDAL STATION SUMMARY STATISTICS

Station	No. of Species*	Diversity	Equit-ability	Richness	g/m^2**	$\#/m^2$**	Silt/Sand Ratio
A1	10	1.70	0.57	1.27	1.50	2623	0.054
A2	11	2.28	0.66	1.84	3.98	2430	0.023
A3	8	0.68	0.23	1.09	8.17	6772	0.034
A4	5	0.45	0.20	0.75	2.79	2161	0.005
A5	6	0.53	0.21	0.99	1.61	1688	0.006
B1	7	0.81	0.29	0.98	6.66	4902	0.018
B2	10	2.54	0.76	1.53	5.16	3805	0.019
B3	12	2.04	0.57	2.05	3.87	2279	0.018
B4	9	1.52	0.48	1.43	3.76	2945	0.007
B5	12	1.71	0.48	1.89	5.59	3666	0.002
C1	9	2.11	0.67	1.48	6.88	2580	0.066
C2	11	1.77	0.51	1.70	5.59	3827	0.049
C3	10	1.50	0.45	1.65	2.26	2537	0.015

* or Taxa separtely identified, see Annex 1. Since this number is used in calculating the various qualitative statistics, they may be slight under or over estimations.

** Based on area of quadrat sampled.

TABLE B15. INTERTIDAL STATION GRAIN SIZE ANALYSES

Station	% Gravel (> 2 mm)	% Sand (2 mm - 63μ)	% Silt (63 - 4μ)	% Clay (< 4μ)
A1	0.1	92.3	5.0	2.7
A2	0.1	97.0	2.2	0.8
A3	0.1	94.8	3.2	2.0
A4	0.1	99.3	0.5	0.2
A5	0.1	99.1	0.6	0.3
B1	0.1	97.5	1.8	0.7
B2	0.1	94.8	4.3	0.9
B3	0.1	97.6	1.8	0.6
B4	0.1	98.8	0.7	0.5
B5	0.1	99.7	0.2	0.1
C1	0.1	92.7	6.1	1.2
C2	0.1	94.2	4.6	1.2
C3	0.1	97.0	1.5	1.5

$$R = \frac{s-1}{\log_e N} \qquad (3)$$

All taxa identifed were considered "species" for these calculations.

Fauna encountered at Station A1, north of the Westshore causeway, were largely very small estuarine forms. The resistant polychaete, *Capitella* was also present. At A2, the clam *Macoma inconspicuata* was the most numerous organism present. The amphipod *Eohaustorius washingtonionus*, which tends to be found in sandy areas of the Pacific Northwest was also present. A3 had a very large number of small (2 mm) *Macoma* present, accounting for the relatively high sample weight (8.17 g/m^2). At A4, still lower in the intertidal, the polychaete *Capitella*, whose numbers had been declining with depth, is no longer present. Stations A4 and A5 both had large numbers of *Macoma*.

Station B1, high in the intertidal and south of the Westshore causeway, also had high numbers of *Capitella*. B2 had a more diverse fauna present, including Harpastizoid copepods. B3 was similar to B2. B4 had the first clump of *Macoma* in line B and also the first appearance of the amphipod *Paraphoxus* in line B. The taxonomy of *Paraphoxus* remains unclear and is found in the literature under the generic name *Trichophoxus* at will. B5 is a similar station, with the very common polychaete *Scoloplos armiger* having the highest numeric presence.

Line C stations, at the centre of the intercauseway area, were similar to line B stations. Again, at station C1, high in the intertidal, *Capitella* is present. Large numbers of immature Spionidae also were present. These small polychaetes were too immature and small ($<$ 4 mm length) for positive specific identification. C2 was roughly similar to C1, again having many *Capitella* and immature spionid worms. C3 showed the first large clump of very small *Macoma* on line C.

Subtidal Benthos:

Detailed subtidal results are in Annex B2. Tabular summaries of statistics and grain size analyses are in Tables B16 and B17, respectively. Statistical analyses were performed as for intertidal stations. Numbers and weights per metre squared were based on total samples (replicate sum) and grab bite area.

Subtidal stations on line A were a direct continuance of the intertidal line A stations (Figure B6) and are reported in order of increasing water depth. Station A6 contained the only *Eohaustorius* (Arthropoda:Amphipoda) collected in the subtidal. The *Macoma* present (in large numbers) were likely *inconspicuata*, but were too small for positive identification. The presence of the ophiuroid points to the lessening of estuarine conditions at this level. Station A7 is similar, although siltier and having fewer overall numbers and biomass. Station A8 marks the decline of the *Macoma* distribution. This station was also the second most silty of the collection and a number of relatively uncommon (for the area) animals were present. These included the polychaetes *Spiophanes bombyx* and *Pectinaria* sp. and the razor clam, *Solin sicarius*. Station A9 was sandy and had lower numbers of animals present. The shell debris residue was largely *Macoma*. Station A10 had *Ptilosarous* (Coelenterata:Anthozoa), the sea pen and the relatively uncommon polychaete, *Magilona*. Gastropods present were very small.

Station A11 had fewer species and animals than A-10, but higher weights. The empty polychaete tubes in replicate 2 were interesting in that they were constructed of wood pieces and grass and were very large and unorganized.

Stations along line B, a continuance of the intertidal stations, were located across the borrow pit and terminal loading areas.

TABLE B16. SUBTIDAL STATION SUMMARY STATISTICS

Station	No. of Species*	Diversity	Equit-ability	Richness	g/m^2**	$\#/m^2$**	Silt/Sand Ratio
A6	29	2.85	0.59	3.99	14.05	7062	0.039
A7	32	2.28	0.46	4.87	5.80	3635	0.274
A8	61	4.63	0.78	8.88	22.87	5361	0.945
A9	58	4.65	0.79	8.96	8.19	3011	0.031
A10	43	3.91	0.72	6.97	6.68	2608	0.205
A11	30	3.12	0.64	5.01	9.07	2060	0.016
B6	41	3.69	0.69	5.75	64.64	6609	0.004
B7	46	4.25	0.77	6.75	17.89	4952	0.054
B8	51	4.14	0.73	6.68	75.16	11428	3.195
B9	54	4.56	0.79	8.41	15.25	3446	0.026
B10	36	4.22	0.82	6.44	11.72	1443	0.034
B11	30	3.70	0.75	5.25	4.41	1581	0.004
C4	38	2.98	0.57	5.12	15.88	8606	0.007
C5	41	2.58	0.48	5.52	16.63	8996	0.011
C6	40	4.01	0.75	6.55	4.66	2419	0.058
C7	51	4.58	0.81	8.35	4.16	2514	0.042
C8	35	3.77	0.73	6.02	5.10	1777	0.002
C9	39	4.21	0.80	6.88	3.09	1581	0.003

* or taxa, see Table

** based on total sample and grab bite area

TABLE B17. SUBTIDAL STATION GRAIN SIZE ANALYSES

Station	% Gravel (> 2 mm)	% Sand (2 mm - 63μ)	% Silt (63 - 4μ)	% Clay (< 4μ)
A6	0.1	93.9	3.7	2.4
A7	0.2[1]	74.1	20.3	5.4
A8	0.1	47.3	44.7	8.0
A9	1.2	90.4	2.8	5.6
A10	0.3[2]	79.2	16.2	4.3
A11	0.1	96.7	1.5	1.8
B6	0.1	98.2	0.4	1.4
B7	0.2	92.3	5.0	2.5
B8	0.2[3]	19.0	60.7	20.1
B9	0.1	95.5	2.5	2.0
B10	0.1	94.9	3.2	1.9
B11	0.1	98.5	0.4	1.1
C4	0.1	98.6	0.7	0.7
C5	0.1	98.2	1.1	0.7
C6	0.1	93.1	5.4	1.5
C7	0.4[2]	94.5	4.0	1.1
C8	0.1[4]	99.3	0.2	0.4
C9	0.1	99.6	0.3	0.1

1. entirely shell fragments
2. some shell fragments
3. organic material
4. wood and shell fragments

Station B6, at LLW, had exceptionally high weights, largely due to the *mytilus* present. The locally uncommon polychaete, *Owenia collaris* (old species name *fusiformis*) was present, as were small *Balanus* on eelgrass and shells. The *Pentidotea* (Arthropoda:Isopoda) collected were very large, up to 3.7 cm. Station B7 was undistinguished excepting the presence of *Owenia*, *Onuphis* and *Scalibregia*, relatively uncommon polychaetes. Station B8 was the siltiest station and had the highest numbers and biomass of this collection. Species were common in muddier bottoms, such as the polychaete *Sternaspis fossor* and the bivalves *Nacula Nuculana* and *oxinopsis* were present. Station B9, back in sand, had lower numbers, but was very diverse. Interestingly enough, the polychaete *Manayunkia aestuarina,* an estuarine animal, was found here, 20 metres below LLW. Station B10 was generally similar, but had fewer animals present. A single *Acita castrensis* (Mollusca:Bivalvia) was found. This animal is usually found in great numbers in mud, but rarely in sandy areas. The inclusion of the Ctenophore *Pleurobrachia* and larvaceans are because they were caught as the grab fell to the bottom. They and some other previously listed animals are, of course, not benthic. Station B11 was typical of this collections' deep stations in having lower numbers and weights than at shallower stations. The polychaetes at Station B11, excepting *Tharyx*, were not sedentary types and most very mobile, similar in this regard to Station B10.

Subtidal stations along line C were a direct continuance of the line C intertidal stations. Station C4, at LLW, again has *Macoma*, illustrating their depth distribution. The spionidae present may be *Spio*, but were too small to be readily identified. Station C5 has a large number of very small (2 mm) *Balanius*. These were attached to shell debris. *Batillaria* sp. is once again present. The species of this gastropod is most likely *attramentaria*, although earlier reported as *zonalis* by other workers (Smith and Carlton, 1975). Stations C6, 7 and 8 are not outstanding in the presence or absence of fauna. Station

C6 has a few of the uncommon polychaete *Spiophanes bombyx* and the gastropod *Trophonopsis*. *Owenia* shows up at Station C7 and *Spiophanes bombyx* again at Station C8. The shell debris at Station C8 is *Macoma* and the low number of replicate 3 may be the result of a gravel pocket. Station C9 has relatively low weights. The polychaete tubes are probably turbellids polychaete tubes.

SCUBA Transects:

Transect 1 (Figure B6), was covered twice, once (1A) obliquely from 50 to 100 m offshore on a southwest heading and once (1B) at 25 - 30 m offshore on a northeast heading. Transect 3A was over a soft bottom that overlaid a firmer muddy layer. The softer surface was not moving in response to water movement during the dive, but could be distrubed with a gentle hand movement. The fauna encountered included sea pens, hermit crabs, many large (20-25 cm) flatfish and evidence of clams. Depths, relative to LLW, ranged from 3 to 5 m. Transect 1B averaged 3 m in depth, along the interface of cobbles and silty sand. The sand was solid and firm, but deeply sculptured. During this transect a few Dungeness crabs, some large flatfish (half as many as in 1A), many small flatfish (2-3 cm), sculpins and hermit crabs were sighted. Also present in the muddy areas were some opliuroids, small whelks and nudibranchs.

Transect 2 started at the center of the south face of Westshore terminal. On shore, below LLW, a rocky shoreline type community including *Laminaria* and *Nereocystis*, was found on the rip rap. The rip rap drops off rapidly to a sandy bottom at 6 m. The sand was sculptured over the entire transect, but most deeply below 10 m (75 m offshore). Scattered spots of silty mud were also noted, and were widest below 10 m. The biota below the rip rap included active Dungeness crabs, sea pens,

numerous gastropods, small flatfish and sculpins (although fewer large flatfish), skate (up to 1m), and dog fish.

Transect 3 was done twice. The first attempt produced little information because visibility was very low (0 - 0.3 m). The second ran out from the terminal over cobbles, then sand, eelgrass and finally loose, soft mud at 100 m. The eelgrass bed was sandy with some mud and contained *Ulva*, cockles and many copulating pairs of Dungeness crabs. Fewer crabs were found in the muddy area. The muddy areas had sculpins, flatfish, shovel-mouthed shrimp (*Crago* sp.) and many ophiuroids, bubble snails and nudibranchs.

Transect 4 substrate was very soft, silty and easily disturbed in the area of the channel, shallower it was similar to Transect 3. Fauna encountered were similar in types and lower in numbers to the muddy areas of Transect 3 except for the presence of large numbers of Buffalo head sculpin.

The last of the SCUBA investigations centered about the piles in the ship loading area. Although two pile sites were circled, the descriptions below stand for both, except at the water's surface and the substrate about the bases. The outer, with a wooden bumper unit, had a much wider zone of *Mytilus* and a firmer mud bottom. The inner (15 m inshore, supporting the loader track), had a very easily disturbed mud bottom. Both sets were covered with *Palamus* below the *Mytilus* zones. Most crabs in the area were near or on the outer piles (both *Cancer magister* and *C. productus*). Also commonly found were anemones (*Metridium* sp.), decorator crabs, yellow sponges, ascidions, bryozoans, tube worms, nudibranchs and hundreds of coon-striped shrimp. In both areas, complete darkness was encountered at 10 m. Organisms encountered appeared clean and coal dust or pieces of coal were not observed. There was little attached algae on the pilings and none on the substrate about the bases of the pilings.

B4.2.3 Discussion

Intertidal Benthos:

Table B18 presents means of summary statistics for each of the three lines. Line A had lower mean diversity and biomass per square metre than lines B and C. Lines B and C were very similar in all respects. Line A had more estuarine forms present, while lines B and C had more marine forms present.

Correlations of numbers and biomass to elevation and silt/sand ratios are hampered by the clumped distributions of some of the species encountered. Diversity and biomass found along line A were similar to that reported by Levings and Coustalin (1975), for their similarly located transect "CP". Lines B and C, which were quite similar, had lower results than Levings and Coustalin's Transect "TSAW", which corresponded to line C. The most glaring difference was in the presence of the polychaete *Manayunkia*, an estuarine form. Although sampling technique and treatment were the same, the time of year sampled was not and this may account, in part, for the difference.

Subtidal Benthos:

Table B19 presents the means of summary statistics for each of the three subtidal lines. Differences between lines are less evident subtidally than intertidally. In fact, once the data are filtered of exceedingly high biomass from clumped distributed numbers and forms (eg. *Mytilus* at Station B6), differences are even less. Within a line the relation between silt/sand ratio and fauna present is more evident (Station B8) but is still not a consistent relationship.

TABLE B18. MEANS OF INTERTIDAL SUMMARY STATISTICS

Summary Statistic	Line A	Line B	Line C
Number of species	8	10	10
Diversity	1.13	1.72	1.79
Equitability	0.37	0.52	0.54
Richness	1.19	1.73	1.61
g/m^2	3.61	5.01	4.91
$No./m^2$	3135	3519	2981
Silt/sand ratio	0.024	0.012	0.043

TABLE B19. MEANS OF SUBTIDAL SUMMARY STATISTICS

Summary Statistic	Line A	Line B	Line C
Number of species	42	43	41
Diversity	3.57	4.09	3.69
Equitability	0.66	0.76	0.69
Richness	6.45	6.55	6.41
g/m^2	11.11	31.51	8.25
$No./m^2$	3956	4910	4316
Silt/san ratio	0.252	0.553	0.020

Below LLW the stations showed higher numbers, diversities, and biomass. Although this may be a result of the sampling technique (a grab sampling to greater depth per area sampled), it is more likely to be a function of elevation and exposure. Distribution of numbers, biomass and diversity generally increased with depth to about 12 m, then decreased with depth to 36 m on all three lines. Line B had more mobile forms present at 27 and 36 m and more sedentary forms at other, shallower stations. This was not so in line A and may be reflective of relative substrate stability (or accretion).

SCUBA Transects:

SCUBA transects about Westshore terminal showed faunal assemblages typical of those found on sand/mud flat substrata. Coal dust was observed in the shallow areas immediately adjacent to Westshore terminal. None, however, was evident along the transects at depth. Also, animals observed in the shallows appeared unaffected. Various organisms had quite densely settled the hard substrate provided by the rip rap and pilings of the facility. The sparseness of benthic macro-algae on the pilings and about their bases is likely the result of shadowing by structures above the water surface and by ships during loading.

In all, the flora and fauna of the area appeared unaffected by the presence of Westshore Terminal. In fact, the addition of solid substrate to the area has provided habitat for more diverse faunal and floral assemblages than would ordinarily be found.

B4.3 GENERAL BENTHIC SUMMARY

Results of the intertidal investigations were similar to those previously reported for the area (Levings and Coustalin, 1975; McGreer, 1975). A strict relation between grain size and numbers or

biomass was not evident. The area between the Westshore and Tsawwassen causeways had less estuarine forms present than the area sampled to the north of the Westshore causeway. The causeways and pilings have provided more stable substrate for epifaunal organisms.

Subtidally there appeared to be little difference between the three lines investigated. Line B, which crossed the "borrow pit" and dredged channel did not appear to have very different forms present at given depths, except at Station B8 which had the highest silt/sand ratio of the entire study. Biomass levels were also highest at that station. Diversities encountered were higher than those at similar depths off Sturgeon Bank (Dept. of Environment, F & MS, 1975).

The sediment collected in the benthic survey was essentially sand (grain size <2 mm, $>63\mu$) with patches of silt ($<63\mu$, $>4\mu$). Lower biomass but much higher diversities were evident in comparison to deeper (100-200 m) areas in the Strait of Georgia (Dept. of Environment, F & MS, 1975).

Qualitatively, from SCUBA transects, the area appears to be typical sand/mud flat, with the expected assemblage of organisms. Many organisms encountered in this and other portions of the study are listed as those appearing in the eelgrass meadows of Puget Sound (Phillips, 1972). Coal dust was observed on the bottom in the vicinity of the coal terminal in the high intertidal area. Concentrations were apparently higher to the west of the pod, as had been observed earlier by Butler (1972). Hard substrates, such as pilings and protective rip rap on the causeway, have been colonized by sessile animals and algae where not shaded.

In all, considering substrata, none of the biota encountered were extraordinary by their numbers, sizes, apparent condition or distri-

bution. Further, there were no biota conspicuous by their absence. The numbers and species of benthos encountered were as would be expected for the time of year and substrate from which they were collected.

B4.4 DUNGENESS CRAB (*Cancer magister*)

This section deals briefly with the biology and commercial aspects of the Dungeness crab. The Dungeness crab resource as concerns recreational or sport fishery use is detailed in Appendix C.

B4.4.1 Background

Dungeness crab range from the Aleutian Islands of Alaska to the west coast of the Baja peninsula, Mexico (MacKay, 1942). In British Columbia, Dungeness are found in shallow, sandy areas. Levings and Coustalin (1975), citing Butler (1954), state that molluscs are the preferred diet and therefore the coarse sediment of the lower delta is good habitat. Small Dungeness are also found in association with eelgrass meadows in the Queen Charlotte Islands (Butler, 1977, pers. comm.) and this association has been observed also at southern Roberts Bank.

Mating takes place from April until September, with the peak in May and June. Mating largely takes place on tidal flats. Females bear eggs mainly from October to June, with hatching occurring from December until June, reaching a peak in March. Larvae are planktonic, metamorphizing to the adult body form over several stages and settling. Growth is most rapid in the summer and fall. Females reach sexual maturity at about four years in age and 10 cm in width; while males reach maturity later. Males reach legal size (6-1/2 inches) at seven or eight years. Very few females attain this size (MacKay, 1942).

Local fishermen have claimed a decline in the crab catch in the southern Roberts Bank area. There are, unfortunately, no detailed records to substantiate or refute this claim. Population levels are known to fluctuate over wide areas but the periodicity, if any, of these fluctuations is unknown (Butler, 1977, pers. comm.).

Local fishermen have also commented on the occurrence of black streaks on the flesh of cooked crabs. Again, the locality of catch, other than Roberts Bank, was unknown.

B4.4.2 Field Studies

Dungeness crabs and shore crabs (*Hemigrapsus nudus*) were collected for dissection to determine the frequency of black streaks, and, if found, to determine the source. *Hemigrapsus* were collected from under rocks near the water's edge on the cobble beach east of the West-shore office on the terminal. *Hemigrapsus* were taken in addition to Dungeness because it was reasoned that if the existing facility was responsible for the black streaks, these crabs, living in closest proximity would be the most affected. Dungeness were collected from the inshore edge of the eelgrass crescent paralleling the concave shore of the coal terminal causeway. *Hemigrapsus* and Dungeness were collected by hand while walking and snorkling. Both species were readily collected.

Hemigrapsus were measured and weighed immediately after collection, then frozen (for storage), and thawed prior to dissection. Dungeness were also measured and weighed immediately, then cooked and the flesh picked in the normal manner for food preparation. Sizes are recorded in Annex 3. No evidence of black streaks were found in the 30 Dungeness or 56 *Hemigrapsus* collected.

Since no evidence of discolouration was found, an additional collection was made. Specimens were collected from the commercial catch taken by a local fisherman who kindly assisted this study, in allowing a biologist to accompany him on a regular pot pulling session. The fisherman regularly sets over 100 pots along Roberts Bank from the U.S. border to Canoe Pass. During June 29, 1977, approximately 300 kg of legal size Dungeness crabs were taken from these pots. Most crabs taken in the pots (10:1) were cast back as undersize. Specimens for dissection were taken from three areas:

1) from the breakwater southeast of the Tsawwassen Terminal eastward toward the shore along the Canada-U.S.A. international boundary; at 7-9 m
2) at the seaward edge of the eelgrass meadow between the two causeways, from midway between the causeways eastward towards the Tsawwassen terminal; at 7-9 m
3) northwest of the Westshore Terminal from 200 to 1000 m offshore; at 7-9 m

These specimens were treated the same as the Dungeness taken earlier. Sizes are recorded in Annex 3. Again, no evidence of discolouration or "black streaks" was found in any of the specimens (49).

B4.4.3 Dungeness Crab Summary

Although both legal and sublegal size Dungeness were apparently quite abundant, the facts of small sample size and lack of adequate catch records (over terms of years) precludes an accurate assessment of abundance. With regard to condition, all crabs caught and observed during the course of this study appeared active and healthy. Further, 79 Dungeness and 56 shore crabs were dissected to ascertain the frequency of the reported flesh discolouration. None of the specimens showed any evidence of "black streaks".

B5.0 FISH

B5.1 INTRODUCTION

The purpose of this review was to identify pertinent life history parameters of important fishes which may be affected by expansion of the Roberts Bank Port facility. Fourteen fish species which may utilize the Roberts Bank area in the vicinity of the Westshore terminal have been considered in this biological assessment. Seven of the 14 species were chosen because of their noted abundance on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975), while the other seven were chosen because they are known to occur in the Fraser River system and are important sport or commercial fishes. The seven species occurring frequently in Roberts Bank catches (Department of Environment, Fisheries and Marine Service, 1975) are as follows:

Pacific herring (*Clupea harengus pallasi*)
chinook salmon (*Oncorhynchus tshawytscha*)
surf smelt (*Hypomesus pretiosus*)
threespine stickleback (*Gasterosteus aculeatus*)
shiner perch (*Cymatogaster aggregata*)
Pacific sand lance (*Ammodytes hexapterus*)
starry flounder (*Platichthys stellatus*)

The other seven species considered are as follows:

pink salmon (*Oncorhynchus gorbuscha*)
chum salmon (*Oncorhynchus keta*)
coho salmon (*Oncorhynchus kisutch*)
sockeye salmon (*Oncorhynchus nerka*)
steelhead (*Salmo gairdneri*)
cutthroat trout (*Salmo clarki*)
Dolly Varden (*Salvelinus malma*)

Other fish species which are known to occur on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975; and Bruce Hillaby, FMS, pers. comm.) but which were not singled out for individual attention are as follows:

ratfish (*Hydrolagus colliei*)
Pacific tomcod (*Microgadus proximus*)
tubesnout (*Aulorhynchus flavidus*)
pile perch (*Rhacochilus vacca*)
Pacific sandfish (*Trichodon trichodon*)
penpoint gunnel (*Apodichthys flavidus*)
crescent gunnel (*Pholis laeta*)
Pacific staghorn sculpin (*Leptocottus armatus*)
sturgeon poacher (*Agonus acipenserinus*)
English sole (*Parophyrs vetulus*)
sand sole (*Psettichthys melanostictus*)

The review of each species consists of basic life history information along with as much specific information as possible on the biology of the species in the Fraser River estuary and on Roberts Bank. In addition to life history data, information is presented on the importance of each species in terms of its commercial or recreational value or in terms of its role in the ecosystem. These data will provide a background against which the impact of the proposed development in the Roberts Bank area may be assessed.

B5.2 PACIFIC HERRING - *Clupea harengus pallasi*

Pacific herring are distributed from northern Baja California to Cape Bathurst in the Beaufort Sea (Hart, 1973). Their worldwide range extends around the North Pacific Basin to Korea. Herring do not occur beyond the continental shelves in mid-Pacific waters (Outram and

Humphreys, 1974). The effective commercial fishery is between San Francisco and Central Alaska (Hart, 1973).

In British Columbia, herring spawn in late winter with the heaviest spawning in March or April (Hart, 1973). Herring spawn primarily above and just below the zero tideline. Spawnings vary in size from a few yards to several miles long with the width dependent upon the extent of marine vegetation and tidal stage at the time of spawning (Webb, 1974).

Spawning in British Columbia may extend for hundreds of kilometers of coastline. During the 25 year period (1940-64) herring spawn along British Columbia averaged 318 km and in 1975 a record high of 655 km was recorded (Webb, 1975).

Herring spawn in waters of reduced salinity at ocean temperatures between 4 and 10^{o}C. The female discharges adhesive eggs onto aquatic plants such as eelgrass or, occasionally, onto rocks or pilings. One square inch of plant surface may be covered with 1000 eggs and, if spawning is intense, several layers of eggs, one over the other, may be deposited. Hatching success decreases with increasing egg-mass thickness (Outram and Hymphreys, 1974). Storms often dislodge this vegetation and cast it on the beach, exposing eggs to desiccation and freezing. Aquatic birds feed on spawn in shallow water or during low tide exposure. On the average only one herring from 10,000 eggs will return to spawn (Outram and Humphreys, 1974).

Young herring from different spawning sites will mingle in common nursery areas. However, at later stages intermixing between morphologically distant populations is reduced. Initially, larvae feed on invertebrate eggs, diatoms and copepods (Hart, 1973). Larval mortality is the result of displacement by water (offshore winds cause larvae

to drift), starvation, hatching abnormalities and predation (Outram and Humphreys, 1974). However, later developmental stages appear to be an important prey species for many fishes in the sea, providing food for such species as chinook and coho salmon (Hart, 1973).

Juveniles congregate in bays and inlets near kelp beds during the summer months and follow the vertical movement of the zooplankton on which they feed. Near the end of the summer, herring migrate out of the coastal areas into feeding grounds on the offshore banks (Outram and Humphreys, 1974). Herring reach sexual maturity after 3 or 4 years and migrate inshore in late fall or winter (Outram and Humphreys, 1974). They nearly cease feeding as they approach the spawning condition in autumn, and migration begins. A period of summer fattening is followed by winter fasting and sexual product ripening at the expense of stored oil (Hart, 1973). After spawning, about half of these fish survive and migrate back to their feeding grounds (Outram and Humphreys, 1974).

Larvae and post-larvae are common in the surface layers of the Strait of Georgia within the influence of the Fraser River during May and June (Hart, 1973). However, Roberts Bank is not a major herring spawning ground nor does it support a major fishery (Outram and Humphreys, 1974). Webb's (1974, 1975) "Boundary Bay" region (which includes all of Roberts Bank and Sturgeon Bank) constituted 0.31% of total British Columbia spawning through 1975, and 0.25% over the 25-year period of 1940 through 1964. Total British Columbia landings in 1975 were approximately 58,700 tons, having a landed value of about 12.5 million dollars. The average contribution of the entire Boundary Bay region would thus be worth approximately $37,500 in annual landed value based on the 1970-1975 average spawning contribution and the landed value of the 1975 catch. It should be noted that the herring fishery has changed appreciably since the closure of the reduction fishery in 1967-68 (Outram and Humphreys, 1974) and thus certain comparisons of landings and values

among years are not valid since the units of measure have changed. Use of a 1975 valuation gives a fairly accurate assessment of the value of the fishery as it currently exists. In the Roberts Bank area a total of 1.4 km of spawn were deposited in 1975 and 3.4 km in 1974 (Webb, 1974, 1975).

In 1973, herring represented the greatest number of fish found in the eelgrass habitat in the intercauseway area, 14,778 from table seines to 291 from tow nets (Environment Canada, Fisheries and Marine Service, 1975). The catch between the causeways was the highest average herring catch on Roberts Bank from table seines. However, this was not true of tow nets, which showed the highest catch/effort north of the Westshore causeway and south of the Tsawwassen causeway. Herring also represented 96% of all the fish caught on Roberts Bank. These data indicate that the Tsawwassen Bay area (between the causeways) serves as an important spawning, rearing and feeding area for a small proportion of the herring contributing to the fishery in the southern Gulf of Georgia. These herring can contribute substantially as larvae and juveniles to the food supplies of salmonids which may use the habitat between the causeways (Department of Environment, Fisheries and Marine Service, 1975).

B5.3 PINK SALMON - *Oncorhynchus gorbuscha*

Adult pink salmon occur in the Pacific and Arctic Oceans, the Bering and Okhotsk Seas, and the Sea of Japan. They have been successfully introduced in the upper Great Lakes. Spawning occurs in most coastal tributaries of western North America extending from the Sacramento River, California to the MacKenzie River Delta in the Canadian Arctic. In northeast Asia, spawning occurs from Peter the Great Bay north to the Lena River (Scott and Crossman, 1973).

Pink salmon are the most abundant salmon in British Columbia (Hart, 1973), and the second most abundant (after sockeye) in the Fraser River system (Department of the Environment, Fisheries and Marine Service, 1975). They spawn in most major rivers (except those along southeast Vancouver Island) and many smaller coastal streams. However, about 75 percent of the stock spawns in only 78 (or 8%) of these rivers (Carl et al, 1973; Hart, 1973; Scott and Crossman, 1973).

Adult pink salmon migrate from the sea to freshwater rivers from June to September, depending on location (Scott and Crossman, 1973). Males and larger fish generally enter the river first and usually do so on high water (Hart, 1973). Spawning migrations usually extend no more than about 65 km upstream, not far from salt water, although upriver movements of about 480 km have been reported (Scott and Crossman, 1973). Most adults exhibit homing behaviour, returning to the stream in which they were spawned. However, some have been captured in spawning streams 600 km from their parent stream (Scott and Crossman, 1973; Hart, 1973).

Spawning occurs in rivers and tributary streams from mid-July to late October. Spawning streams are usually small with medium-sized gravel substrate, although main channels of the Fraser and Yukon rivers serve as pink salmon spawning grounds (Scott and Crossman, 1973). In the Fraser River system, pink salmon exhibit an early peak spawning run in mid-September and a late peak run in early October (Hoos and Packman, 1974). Spawning occurs in the mainstem Fraser below Hope, and in the Chilliwack and Harrison Rivers which are tributary to the system (Hoos and Packman, 1974).

Eggs hatch from late December to late February, depending on water temperature (Scott and Crossman, 1973; Carl et al, 1973). Alevins remain in the gravel from late February to early May until the yolk-sac

is absorbed, then become free-swimming at a length of about 33-38 km (Scott and Crossman, 1973).

Fry commence downstream migrations soon after leaving the redd, usually at water temperatures of 4-5^{o}C (Wickett, 1962). During 1974, peak downstream migration in the Fraser River occurred on April 5 with the median date for duration of downstream movement on April 10 (Department of Environment, Fisheries and Marine Service, 1975). Hoos and Packman (1974) reported young in the Fraser River generally exhibit a random depth distribution during downstream migrations, although most occur nearer the surface in daylight. The downstream migration of an individual generally takes no more than 24 hours (Hoos and Packman, 1974).

Upon reaching estuarine waters, the young form large schools and are active during the day (Scott and Crossman, 1973). They remain in inshore waters during their first summer, then move to deeper, open-sea waters in September. Many young from the Fraser River spend their first summer in less saline waters near the outlet before moving further offshore (Hart, 1973). In some areas young probably disperse along the shoreline several days after completing downstream migrations.

Studies by the Department of Environment, Fisheries and Marine Service (1975) in the Fraser, showed young pink salmon utilize intertidal estuarine areas of the river less than other salmonids. Also, young pinks did not appear to inhabit shore areas of the river where beach seining was conducted. In the same studies, 31 young pink salmon were caught by purse seine during late April and early May, 1974 on Sturgeon Bank. Twenty-seven of these were captured between the middle arm and the Steveston Jetty. None were captured on Roberts Bank. Lengths were from 31-36 mm. Hart (1973) reported young pink salmon off the Fraser River outlet are 102 mm in July. They attain lengths of about 325 mm by the following March.

After spending approximately 18 months at sea, pink salmon return as two-year-old spawning adults. Individuals three years of age have been reported but are uncommon (Scott and Crossman, 1973). Average weight of returning adults is about 2.2 kg and average length is from 432-483 mm (Hart, 1973; Scott and Crossman, 1973). Spawning runs in a given stream occur predictably in even or odd years. Generally, runs occur in the Fraser River and southern British Columbia on odd years and in northern British Columbia on even years. Some streams which support runs each year may have a dominant run one year and a small run the next (Scott and Crossman, 1973).

The food of pink salmon varies with fish size. The young occasionally utilize insect nymphs and larvae while in fresh water, although they spend only a short time there (Scott and Crossman, 1973). From April to June, young from the Fraser River feed primarily on copepods but by July are large enough to utilize chaetognaths, amphipods and euphausids (Hart, 1973). They also feed on young fishes such as herring, eulachon, smooth-tongue, hake, pricklebacks and gobies during their first summer (Hart, 1973). Studies by the Department of Environment, Fisheries and Marine Service (1975) showed that, in the south arm of the Fraser, young pinks feed on amphipods and harpacticoid copepods. On Sturgeon Bank, stomachs of the young contained plankton and estuarine benthos. At sea, foods include euphausids, amphipods, copepods, pteropods, squid and fishes. Adults do not normally feed after entering Pacific Coast spawning rivers (Scott and Crossman, 1973).

Predators of pink salmon vary depending on the life stage of the salmon. Eggs and alevins are occasionally preyed upon by caddisfly larvae and stonefly nymphs. Young are utilized by various stream fishes (salmonids, sculpins, squawfish), birds (kingfishers, mergansers), and mammals (muskrats) (Hart, 1973). Adults are preyed upon by man,

marine mammals and large fishes. According to Scott and Crossman (1973) adults returning to the Fraser River in 1967 had been attacked by Pacific lamprey (*Lampetra tridentatus*).

Estimated average annual spawning escapement of adult pink salmon in the Fraser River during 1957-1972 (odd years only) was 810,000 (Department of Environment, Fisheries and Marine Service, 1975). The estimated average annual number of young migrating downstream in the Fraser during 1965-1974 (even years only) was 193.5 million (Department of Environment, Fisheries and Marine Service, 1975). Hoos and Packman (1974) reported downstream migrations in the Fraser were 143.6 million in 1962 and 284.2 million in 1964, representing freshwater survivals for the previous year's spawn of 9.3 and 11.7%, respectively.

Pink salmon have comprised an increasingly large portion of the commercial catch in Canada and the United States in recent years (Scott and Crossman, 1973). Most are taken by purse seine or gill net as they approach spawning streams (Hart, 1973). About 95% of the catch is canned and the remainder traded fresh or frozen. In the Fraser River, average annual commercial catch (odd years only) of adult pink salmon has been estimated at 2,300,000 fish (Department of Environment, Fisheries and Marine Service, 1975). The total net economic value of the Fraser River pink salmon catch in an average year was estimated at nearly 8 million dollars (Department of Environment, Fisheries and Marine Service, 1975).

Pink salmon gained popularity as a sport fish in British Columbia in the late 1950's when it was found they could be caught by trolling artificial bait (Scott and Crossman, 1973). Pink salmon have comprised no more than 13% of the sport catch of salmon in the lower Fraser River in recent years (Hoos and Packman, 1974).

Once again, it is significant that Department of Environment, Fisheries and Marine Service (1975) found no pink salmon on Roberts Bank.

B5.4 CHUM SALMON - *Oncorhynchus keta*

Chum salmon have the widest distribution of all Pacific salmon. Spawning populations utilize most North American coastal streams from the Sacramento River in California to the MacKenzie River on the Arctic coast. In Asia, chum spawn in coastal streams from the Nakdong River system of the Republic of Korea to the Leng River on the Arctic shore of the U.S.S.R. Most coastal streams of the Japanese islands also have spawning populations. Adults are found in the Pacific and Arctic oceans, the Sea of Japan, Okhotsk and Bering seas (Bakkala, 1970; Hart, 1973; Scott and Crossman, 1973). The southern extent of their range is limited by temperature and is generally located at the 46^{o} latitude (Hart, 1973).

Chum salmon return to their natal streams to spawn and, in the Fraser River system, they spawn in the Stave, Chilliwack, Vedder and Harrison tributaries as well as in the Fraser mainstem (Hoos and Packman, 1974). Sexual maturity is reached between the ages of 2 and 7 years (Scott and Crossman, 1973). The majority of Fraser River chum salmon reach sexual maturity in 4 to 5 years (Department of Environment, Fisheries and Marine Service, 1975). Adult chum salmon approaching sexual maturity leave their high seas feeding areas and generally enter coastal waters between June and November (Bakkala, 1970). Little time is spent in coastal waters before adults migrate upstream to spawn. Chum salmon characteristically stop feeding as they enter fresh water.

Fraser River chum salmon enter the river between August and mid-January. Spawning takes place from October to January (Department of

Environment, Fisheries and Marine Service, 1975). According to Hoos and Packman (1974) adults generally enter the main arm of the Fraser after the third week of September after delaying at the river mouth from one to four weeks. Two peak runs are recognized (Hoos and Packman, 1974), the first occurs between mid-October and early November and the second occurs between mid-November and early December. Spawning migration escapement is dependent on fishing pressure and environmental factors influencing survival in ocean and freshwater environments. An estimated annual average of 340,000 chum salmon reach Fraser River spawning grounds (Department of Environment, Fisheries and Marine Service, 1975).

Eggs and larvae develop in the streambed gravel. After reaching the fry stage they emerge from the gravel. Fry emergence occurs in March through May (Bakkala, 1970). Emigration may begin immediately or the fry may wait from a few days to several weeks to begin downstream migration. In the Fraser River system emigration begins in mid-March with the peak of migrants passing Mission (80 km upstream from the mouth) between April and May. During their estuarine residence juvenile chum salmon grow rapidly and feed on insect larvae (Hart, 1973) and harpacticoid copepods (Sibert et al, 1977). The estimated average annual downstream migration of chum fry from the Fraser River system is 75.7 million fish (Department of Environment, Fisheries and Marine Service, 1975).

After leaving freshwater, juveniles remain in the coastal waters adjacent to their natal stream. By mid-August most will have left these waters on their migration to high seas feeding areas (Bakkala, 1970). Early ocean life is the time of highest mortality for chum salmon. In Hook Nose Creek, British Columbia, survival of juvenile stage chum in the coastal environment has been reported to be 5.4% (Bakkala, 1970). Survival rates of 7.8%, 56.6% and 93.0% for the egg to fry, pelagic and coastal adult stages, respectively, have also been reported (Bakkala,

1970). The causes of mortality are not well understood but include predation, and unfavourable water temperatures and salinity.

In sampling of Roberts Bank for juvenile salmon, chum comprised only 1% of the total salmon catch (Department of Environment, Fisheries and Marine Service, 1975). Most of the juvenile chum salmon caught in the Fraser estuary were caught on Sturgeon Bank, and most of those on Sturgeon Bank were taken on April 25 and April 26, 1973. In this study, a number of different capture techniques were used. Seven of the nine juvenile chum salmon taken on Roberts Bank by table seine were caught in the intercauseway area during August. Chum accounted for 2% of the juvenile salmon caught on Roberts Bank by table seine. The total number of chum caught by all gear during this study (March 28 to September 21) on Roberts Bank was 22. The catch per set of chum salmon was highest in the South arm of the Fraser and was higher on Sturgeon Bank than on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975).

Analysis of stomach contents of the juvenile chum caught between the Roberts Bank causeway and Tsawwassen Ferry Terminal show that 99.3% of the items eaten were plankton (*Parathemisto pacifica*). In contrast, larval and juvenile fish, and freshwater and terrestrial invertebrates were the important food items of juvenile chum salmon caught elsewhere on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975).

Chum salmon are not as commercially important as other Pacific salmon because of the pale colour and low fat content of the canned product (Hart, 1973). Most commercially caught chum salmon is sold fresh or frozen. Chum is a favoured salmon of Indians because it smokes well. The average annual commercial catch of Fraser River chum is

estimated to be approximately 510,000 fish having a total net value of 3.2 million dollars (Department of Environment, Fisheries and Marine Service, 1975). Chum are not pursued by sportsmen.

B5.5 COHO SALMON - *Oncorhynchus kisutch*

Spawning populations of coho salmon utilize North American coastal streams from Monterey Bay, California to Point Hope, Alaska. The majority of the North American population occurs between Oregon and southeastern Alaska. Asian populations spawn in coastal streams from the Anadyr River, U.S.S.R., south to Hokkaido, Japan. Coho salmon usually do not range far out to sea; most appear to remain within 1900 km of shore. Adults have occasionally been reported as far south as Baja, California (Hart, 1973; Scott and Crossman, 1973).

Sexual maturity usually is reached between the ages of 3 and 4 years (Hoos and Packman, 1974). Normally coho spend two summers (approximately 18 months) in the open ocean before migrating to fresh water for spawning. Occasionally males, and more infrequently females, may reach sexual maturity the first fall after migrating to salt water (age = 2 years). In British Columbia, precocious individuals occur mainly in the southern spawning areas (Scott and Crossman, 1973).

Mature coho salmon leave their feeding areas in the open ocean and migrate south along the coasts of Alaska and Canada on their way to freshwater spawning areas. During this migration they grow rapidly while feeding mainly on fish (Hart, 1973). Coho salmon have a very strong tendency to return to their natal stream. Scott and Crossman (1973) reported that 85 percent of spawners return to their natal stream.

Before leaving salt water, coho adults usually congregate at the mouth of their natal river system. Their movement into fresh water is often triggered by the increased river flows caused by fall rains (Scott and Crossman, 1973). In the Fraser River, migrating adults enter the main stem between July and December (Department of Environment, Fisheries and Marine Service, 1975; Scott and Crossman, 1973). Escapement of migrating spawners is dependent on fishing pressure and the environmental conditions influencing survival in ocean and freshwater environments. An estimated annual average of 63,000 coho salmon reach Fraser River spawning grounds (Department of Environment, Fisheries and Marine Service, 1975).

Coho salmon generally select smaller streams for spawning (Hart, 1973; Hoos and Packman, 1974). For this reason the Fraser River is only moderately utilized by coho. Little information is available on coho salmon in the Fraser River but a few are thought to spawn in the main stem above Agassiz (Hoos and Packman, 1974). Spawning occurs between September and March with peak spawning periods occurring from October to November and in December (Hoos and Packman, 1974).

Emergence occurs between early March and late July (Scott and Crossman, 1973). Migration to salt water may begin immediately, but more often the juveniles remain in fresh water through March or April of the following year.

Just prior to migration to salt water, juvenile coho become more active and form small schools. At this time they are about 10 cm in length (Scott and Crossman, 1973). Migration itself is accomplished by the juveniles (smolts) moving into swift current and being swept downstream (Hart, 1973). Often the peak migration period coincides with spring and summer freshets (Hoos and Packman, 1974). In 1974, approxi-

mately 2.1 million coho smolts migrated through the Fraser River (Department of Environment, Fisheries and Marine Service, 1975).

Coho smolts generally arrive at the mouth of their natal stream in late May (Scott and Crossman, 1973). They are thought to remain in the estuary or lower river through the spring and summer before moving to open ocean feeding areas (Hoos and Packman, 1974; Scott and Crossman, 1973). Not all juveniles migrate to open ocean. Occasionally individuals remain in fresh water (Scott and Crossman, 1973). Others will take up residence in the Strait of Georgia (Hart, 1973). Both those that remain in fresh water and in the Strait of Georgia grow less than coho that migrate to the open ocean.

In sampling of the Fraser River Estuary for juvenile salmon, coho comprised 29 and 16% of the total catch on Sturgeon and Roberts Banks respectively (Department of Environment, Fisheries and Marine Service, 1975). One thousand four hundred and eleven juvenile coho were caught in 371 sets equalling an average catch per set figure of 3.8 coho for Sturgeon and Roberts Banks together. In comparison, 1,583 coho juveniles were caught in 359 sets in the main stem Fraser River, equalling an average catch per set figure of 4.4. The sampling period lasted from March 28, to September 12, 1973. Most juvenile coho were caught in June by tow nets at inshore sampling stations on Sturgeon Bank. The average catch per set over the entire sampling period for tow netting was 16 at Sturgeon and 4 coho juveniles at Roberts Banks. Besides tow nets, purse seines and table seines were used. There was little difference in average catch per set figures for either of these gear types between Roberts and Sturgeon Banks. Average catch per set of juvenile coho was 2 for purse seing and 1 for table seine on both Roberts and Sturgeon Banks.

Larval and juvenile herring and other fishes were the most important food items in terms of biomass, for juvenile coho on Roberts and Sturgeon Banks (Department of Environment, Fisheries and Marine Service, 1975). In the intercauseway area, larval and juvenile fish comprised 99.6% of the items in the juvenile coho stomachs examined. In the sample areas north of the Westshore Terminal, benthic organisms and plankton (*Parathemisto pacifica*) were also important.

Coho salmon have long been an important commercial and sport fish throughout their range. The catch of coho from the Fraser River is variable from year to year, but showed signs of declining between 1953 and 1967 (Hoos and Packman, 1974). The average annual commercial catch of Fraser River coho is 142,731 fish (1,141,800 pounds) having a total net value of almost a million dollars ($1973) (Department of Environment, Fisheries and Marine Service, 1975).

In the Strait of Georgia, most coho are caught between July and September. Most of these are caught by trollers between July and mid-August. Many fish are also taken by gillnet and purse seine from river mouths and inlets in August (Scott and Crossman, 1973). Highest quality coho caught by trolling, gillnetting or purse seining are usually sold fresh or fresh-frozen. The remainder is canned, smoked or mild cured. Indians take an estimated 85,000 pounds of Fraser River coho each year (Hoos and Packman, 1974). Coho are taken in the Strait of Georgia as well as the estuary and main stem of the Fraser River. The estimated annual sport catch is between 450 and 2,975 adults and 2,000 and 14,000 precocious individuals (Hoos and Packman, 1974).

B5.6 SOCKEYE SALMON - *Oncorhynchus nerka*

Sockeye salmon occur throughout the North Pacific Ocean ranging from the Sacramento River, California, north to the Canadian

Arctic and westward to the Sea of Okhotsk, near Japan. Sockeye abundance along the Asian coast is centered around the Kamchatka Peninsula (Hart, 1973). The primary areas of abundance of this commercially sought species range from the Columbia River to Bristol Bay, Alaska, with the heaviest concentrations centred around the Fraser River in British Columbia (Hart, 1973).

Adult sockeye salmon migrate eastward over the continental shelf toward British Columbia during the summer months (Hart, 1973). The time of arrival at the estuary or river mouth is related to the distance upriver which must be travelled. Generally early arrivals will migrate further upriver to spawn (Scott and Crossman, 1973).

Verhoeven and Davidoff (1962) discovered from adult sockeye tagging studies, that the principal migration extends through the Strait of Juan de Fuca past Salmon Banks, South Lopez, Rosario Strait, Lummi Island and on to Point Roberts. They also report a phenomenon occurring after September 1, during the delayed late summer run near the mouth, where prevalent northwesterly winds and strong ebb tides force the salmon from the Fraser's mouth back to the Point Roberts area. This same phenomenon is described in Hoos and Packman (1974) and is termed "blowback" or "driftback".

Sockeye stocks originating from British Columbia normally reside somewhat more than one year in fresh water and 2 or more years in salt water (Hart, 1973). The average lifespan is composed of four summers in salt water and two winters in fresh water (Carl, 1973; Hart, 1973; Ricker, 1950). However, precocious males or "jacks" may return to their natal streams after three years (Carl, 1973). Sockeye demonstrate a cyclic dominance in the Fraser River, yielding dominant (every fourth year) and subdominant years (Ricker, 1950).

The prespawning migration in the Fraser River first occurs during early July, when fish move immediately into fresh water and quickly upstream. Later runs of sockeye appear in early August, delay at the river mouth from 19-34 days, and proceed slowly upstream (Hoos and Packman, 1974; Verhoeven and Davidoff, 1962). Time of entry into the Fraser River "...varies between years, between cycle years, between races within a cycle year, and between cycle years within a particular race" (Hoos and Packman, 1974, p. 108). Typically, mature fish enter fresh water and arrive near their natal stream in early summer and remain until fall when spawning occurs (Carl, 1973; Scott and Crossman, 1973).

The presence of a lake is generally a requisite for successful sockeye spawning and rearing. Most fish spawn in tributaries to a lake, however, some fish may spawn on the lake's shoreline or in the lake's outlet. Occasionally they will spawn in systems without lakes (Hart, 1973; Scott and Crossman, 1973); however, sockeye do not spawn in the Fraser River mainstem.

After emergence, the fry proceed to the lake where they are found principally along the shoreline (Hart, 1973). Young sockeye in lakes consume zooplankton and insect larvae. Predators of young sockeye include rainbow trout, coho salmon, Dolly Varden, char, squawfish, and the prickly sculpin (Hart, 1973).

Downstream migration occurs in the spring when the sockeye have obtained lengths ranging from 6.0 to 9.5 centimeters (Hart, 1973; Scott and Crossman, 1973). Downstream migration occurs both day and night in the turbid waters of the Fraser (Hoos and Packman, 1974). Sockeye salmon smolts remain in brackish water during the early summer. During this period food consists of various insects, crustaceans, and larval and young fish such as the sand lance, eulachon, hake, herring,

pricklebacks, starry flounder, big eye whiting and rockfishes (Hart, 1973). The food of the young sockeye on Roberts Bank consists of larval benthos and larval and juvenile fish (Department of Environment, Fisheries and Marine Service, 1975).

The average annual escapement for Fraser River sockeye was 1,250,000 from 1957 to 1972 and the average annual catch was 3,900,000 fish, while the number of downstream migrants averaged 45,000,000 over the period 1965-1974 (Department of Environment, Fisheries and Marine Service, 1975). In the areas of Sturgeon and Roberts Banks young sockeye accounted for only 2% of the salmonid catch. Despite the fact that there were nearly three times as many sockeye as chinook salmon among the downstream migrants and nearly 20 times as many sockeye as coho, both chinook and coho were much more abundant on Sturgeon and Roberts Banks (Department of Environment, Fisheries and Marine Service, 1975). Furthermore, it was reported (ibid) that juvenile sockeye catches were significantly lower on Roberts Bank than on Sturgeon Bank in both offshore and intertidal areas. From an examination of the catch records it appears that sockeye were more abundant on Sturgeon Bank during the sampling period May 7-9 when the downstream migrants appeared in great numbers (ibid); however, juvenile sockeye were not abundant in any subsequent sampling of either Sturgeon Bank or Roberts Bank. It would appear that juvenile sockeye do not remain in the near vicinity of the Fraser River for very long prior to moving to sea. This observation is in accord with other literature on the sockeye salmon (see Hoos and Packman, 1974).

The sockeye salmon supports a large commercial fishery in British Columbia. From 1951 to 1961, the annual catch ranged from 2.84 million to 12.04 million fish and in 1968 the British Columbia catch of 41.2 million pounds had a landed value of 15.6 million dollars (Scott and Crossman, 1973). The Canadian catch of Fraser River sockeye in 1968 was 5.3 million pounds (Hart, 1973). The average annual commercial catch of

Fraser River sockeye was estimated at 23,523,200 pounds with a net economic value of more than 22 million dollars (Department of Environment, Fisheries and Marine Service, 1975). Almost the entire catch of sockeye salmon is canned and there is very little sport fishing for this species (Scott and Crossman, 1973).

B5.7 CHINOOK SALMON - *Oncorhynchus tshawytscha*

Adult chinook salmon occur in the Pacific Ocean, in the Bering and Okhotsk Seas, the Sea of Japan, and rarely, in the Arctic Ocean (Scott and Crossman, 1973). Chinook are anadromous in large rivers flowing into these seas. Young and spawning adults range from southern California's Ventura River through Oregon, Washington and British Columbia (Hart, 1973). In British Columbia, chinook salmon ascend all major streams including migration up the Yukon River to spawn in tributaries of Bennett and Teslin Lakes (Carl et al, 1973). Chinook adults appear in certain British Columbia rivers in August and September, and egg deposition occurs during October and November (Carl et al, 1973). They spawn either immediately above the tidal limit or migrate hundreds of miles upriver (Hart, 1973).

Generally, runs in more northerly rivers occur earlier. However, chinook appear off the mouth of the Fraser River as early as January and their run reaches a maximum in August and September. Spawning time varies with time of arrival at the river mouth, area, and length of river migration (as much as 960 km in the Fraser River). Spawning occurs in the Fraser River system from July to November (Scott and Crossman, 1973). Several runs are recognized in the Fraser River system (Hoos and Packman, 1973) each of which represents a run to a Fraser tributary or group of tributaries. Chinook utilize about 260 British Columbia streams but 50% of the production comes from only 14 streams, one of which is the Fraser River (Scott and Crossman, 1973).

Usually young chinook migrate to sea soon after hatching, however, they may remain one or two years in fresh water. Young chinook salmon are found off the mouth of the Fraser River from April on. There they are 4 to 5 centimeters long in April, 9 centimeters in June, and 13 centimeters by July (Hart, 1973). Food at this stage was found to include herring, sand lance, eulachon, zooplankton, insects and crustaceans (Hart, 1973). In a recent study by the Department of Environment, Fisheries and Marine Service (1975) young chinook on Roberts Bank were found to consume primarily larval and juvenile fish. Chinook just north of the Westshore Terminal consumed 61.5% fish, 18% estuarine benthos and 14.9% plankton; however, chinook found in the intercauseway area consumed 92.7% fish.

Chinook migrate northwest along the coast before returning to spawning streams (Hart, 1973). The major growth takes place in the sea, the fish becoming mature in three to seven years (Carl et al, 1973). In Canada, most chinook spend 2-3 years in the sea but spawning adults have been found as old as 9 years (Scott and Crossman, 1973). Fish make up the bulk (97%) of adult food in the ocean. Herring and sand lance are the most frequently eaten fish (Scott and Crossman, 1973).

The estimated average annual spawning escapement for Fraser River salmon from 1957-1972 was 51,000 chinook while the estimated average annual number of downstream juvenile chinook migrants was 16.8 million from 1964-1974 (Department of Environment, Fisheries and Marine Service, 1975). In this study chinook was found to be the second most abundant fish on Roberts Bank and represented 67% of the juvenile salmon caught on Sturgeon and Roberts Banks combined (Department of Environment, Fisheries and Marine Service, 1975).

Sampling of Sturgeon Bank and Roberts Bank was conducted in spring and summer, 1973 using purse seines, table seines, and tow nets (Department of Environment, Fisheries and Marine Service, 1975). The most successful sampling gear for chinook was the tow net yielding an average catch per effort of 25 on Sturgeon Bank and 13 on Roberts Bank. The purse seine had an average catch of 10 per set on both Roberts Bank and Sturgeon Bank. The table seine was the least successful gear with an average catch per set of only 3 chinook on Sturgeon Bank and 4 chinook on Roberts Bank. Data from tow nets indicated chinook were generally more abundant inshore than offshore and that they were more abundant on Sturgeon Bank than Roberts Bank. Based on average tow net catch/effort chinook appeared to be less abundant in the intercauseway area than in other areas on Roberts Bank; however, this pattern was not evident in table seines. The areas of Sturgeon Bank and Roberts Bank are obviously important rearing areas for chinook when one considers these catch data in conjunction with the estimates of downstream migrants of chinook and other salmon and the relative abundance of these species on the banks. However, the intercauseway area may be less important as a physical habitat than other areas on the banks.

The chinook salmon is the most desirable commercially harvested fresh fish among the Pacific salmon (Scott and Crossman, 1973). The catch is taken primarily by trolling and gillnetting. Additionally, a large sport fishery exists for chinook salmon. The average commercial catch of Fraser River chinook salmon was estimated at 2,378,300 pounds having a total net value of $2,259,400 (Department of Environment, Fisheries and Marine Service, 1975). Much of the British Columbia commercial catch of chinook is composed of fish from the Columbia River and the total British Columbia commercial catch may amount to more than 13 million pounds in a good year. Sport fishermen may land almost another million pounds (Scott and Crossman, 1973; Hart, 1973).

B5.8 CUTTHROAT TROUT - *Salmo clarki*

Cutthroat trout occur in fresh, brackish or salt water in North America, mostly west of the Rocky Mountains (Scott and Crossman, 1973); from northern California through Oregon, Washington and British Columbia to Prince William Sound off the coast of Alaska. In British Columbia cutthroat occur in the coastal area and inland as far as Ashcroft (Hart, 1973).

Adult anadromous cutthroat return to fresh water to spawn in late autumn and early winter. Spawning individuals are found in the Cowichan River, Vancouver Island, as early as November (Scott and Crossman, 1973). "Sea-run" cutthroat from the Fraser enter the mainstem to spawn in sloughs, meadowland streams and small tributaries between the mouth and Hope (Hoos and Packman, 1974). Spawning time is variable from November through May in the Fraser system (Hoos and Packman, 1974).

Even in the coastal area, some fish remain in freshwater at all times, whereas others may go to sea. Hart (1973) reported the cutthroat as mainly freshwater and anadromous from estuaries where they move in and out with the tide.

The habitat of the fish is gravelly, lowland coastal streams and lakes, small rivers and estuaries or the sea near shore (Scott and Crossman, 1973). Fry and older fish are heavy predators on migrating salmon and the adult food items include planktonic crustaceans, crayfish, salmon eggs, dead salmon, and aquatic and terrestrial insects. In the Fraser River estuary cutthroat feed on small fish and crustaceans (Hoos and Packman, 1974).

The cutthroat trout may be an occasional visitor to the area of Roberts Bank between the Roberts Bank Causeway and the Tsawwassen

Ferry Terminal. However, a recent study (Department of the Environment, Fisheries and Marine Service, 1975) noted the capture of only three cutthroat on Roberts Bank.

The cutthroat trout is an important sport fish in inland areas (Scott and Crossman, 1973). It is not as highly regarded among anglers as steelhead. Commercial fisheries for cutthroat are small or nonexistent, however cutthroat are raised commercially in the southwestern United States (Scott and Crossman, 1973).

B5.9 STEELHEAD - *Salmo gairdneri*

Steelhead is the anadromous form of rainbow trout. Rainbow trout originally occurred only in North America, mainly west of the Rocky Mountains from extreme northern Baja California, to the Kuckokwim River, Alaska (Scott and Crossman, 1973). It has been introduced throughout North America as well as in many other parts of the world (Hart, 1973; Scott and Crossman, 1973). Steelhead occur in coastal streams and rivers from northern California to Alaska (Smith, 1969). Steelhead have been observed as far out to sea as 150 W longitude (Hart, 1973). A typical river system in British Columbia could be expected to contain both resident rainbow trout and steelhead (Scott and Crossman, 1973).

While in salt water, steelhead adults feed mainly on fish and various crustaceans (Hart, 1973). Ocean life may last a few months to several years (Hoos and Packman, 1974). Sexual maturity is usually reached between 4 and 6 years of age (Carl et al, 1973). In the Fraser River, two distinct spawning runs of steelhead exist, a summer run entering the river between June and September and a winter run entering between November and April (Hoos and Packman, 1974). Both runs spawn in the spring. Tendencies toward summer and winter spawning runs appear to be inherited and are found in many rivers (Hart, 1973). Generally the

summer run of steelhead will move farther up a river system to spawn than winter run steelhead. Summer run fish usually are not sexually mature when they enter a river, while winter run fish are mature (Smith, 1969). Rainbow trout (including steelhead) mainly spawn in small tributaries of rivers, and inlet or outlet streams of lakes (Hart, 1973). Unlike Pacific salmon, steelhead occasionally survive spawning. Hoos and Packman (1974) reported that approximately 10 percent survive spawning to spawn a second time. They also reported that less than 1 percent survive to spawn a third time.

Migration of juveniles to sea generally occurs during spring freshets (Hoos and Packman, 1974). Before moving out to sea, young steelhead are thought to remain near the mouth of their natal river (Hoos and Packman, 1974). Young steelhead occur in the Strait of Georgia off the outlet of the Fraser River and in Saanich Inlet (Hart, 1973). In June these fish were feeding on insects, euphausids, copepods, amphipods and other crustaceans, *Sagitta* and young fish such as sand lance, herring, eulachon, red devil, searcher and smooth tongue.

In Canada and the United States the steelhead is considered a sport fish. Indians in British Columbia harvest steelhead commercially (Hoos and Packman, 1974). Hoos and Packman (1974) also reported that steelhead are taken incidentally while gillnetting for salmon at the Fraser River mouth and upstream near Mission City. They also reported that Indians fishing the Fraser River and Howe Sound area (including the Squamish system) harvested between 3875 (1965) and 1510 (1969) steelhead. Steelhead are pursued by sportsmen in many coastal and tributary streams. The Indian commercial catch of steelhead has been declining since 1960 and sport catches have been declining since 1966 (Hoos and Packman, 1974).

In a recent study which sampled the Roberts Bank fishes (Department of Environment, Fisheries and Marine Service, 1975), steelhead were not noted as an abundant fish. However, it is possible that a portion of the Fraser River steelhead run may occasionally visit the Roberts Bank area. These fish would be relatively large and would most likely feed on the smaller fishes which occupy Roberts Bank.

B5.10 DOLLY VARDEN - *Salvelinus malma*

The Dolly Varden ranges from northern California through Oregon, Washington, British Columbia and southeastern Alaska to the Aleutian Islands (Hart, 1973). There are anadromous and nonanadromous populations from Washington north. The anadromous fish do not move out into the open ocean but remain close to shore near river mouths (Scott and Crossman, 1973). In British Columbia, Dolly Varden occur through the coastal areas but are more abundant in salt water toward the north (Hart, 1973). Some estuarine Dolly Varden occur in the Lower Fraser River while others migrate to sea as juveniles (Hoos and Packman, 1974).

Scott and Crossman (1973) provide details of the Dolly Varden's biology. In nonanadromous populations the young may spend from several months to 3-4 years in streams, moving then to a lake, just as the anadromous stocks move to sea. Habitat of the young is the gravelly spawning stream in which they hatched. Anadromous stocks migrate to sea in late May to early June. They spend from 60-160 days at sea, moving only short distances from the river mouth and staying in tidal water. Adults return to the Fraser River to spawn in late summer or fall (Hoos and Packman, 1974). Summer food of stream resident young is frequently young salmon or insects, snails and leeches. In estuaries, greenling, sculpin, euphausids, polychaetes and herring have been found in Dolly Varden stomachs.

It is likely that Dolly Varden are only occasional visitors to Roberts Bank in the intercauseway area and that this area is not an integral part of Dolly Varden habitat. Sampling by the Department of Environment, Fisheries and Marine Service (1975) did not find Dolly Varden to be an abundant species on either Sturgeon or Roberts Banks.

The Dolly Varden is not highly regarded as a sport fish by anglers and it may be considered a nuisance by some because of its consumption of salmon and trout which have more commercial and recreational value than the Dolly Varden (Scott and Crossman, 1973). Commercial fisheries which once existed for this species are no longer important (Scott and Crossman, 1973).

B5.11 SURF SMELT - *Hypomesus pretiosus*

The surf smelt is an abundant fish in British Columbia waters. It is found all along the Pacific coast of North America from southern California to Prince William Sound and Chignik Lagoon on the Alaska Peninsula (Hart, 1973). They are known from many areas in British Columbia where the waters are brackish (Hart, 1973).

Surf smelt spawn in most months of the year on protected beaches where the adhesive eggs are protected from desiccation and excessive surf action. Surf smelt spawn at high tide over several days and each female may produce from 1,320 to 29,950 eggs (Hart, 1973). It is believed by some investigators that an individual may spawn several times in a single season (Hart, 1973).

The eggs, which are buried in the sand, hatch in 10-11 days during the summer, but eggs spawned in the winter take much longer to hatch (Hart, 1973). The larvae are approximately 3 mm long at hatching (Hart, 1973). The subsequent life history is not well known, but in

British Columbia they appear to live to an age of 3 years (Hart, 1973). Age determination cannot be accomplished with certainty, but samples from the Strait of Georgia in April and June showed size groups, centering around 80 and 145 mm total length, which may have represented age groups I and II (Hart, 1973).

The surf smelt was the seventh most frequently caught fish on Roberts Bank in a recent study (Department of Environment, Fisheries and Marine Service, 1975), and it probably serves as a minor food source for the chinook and coho salmon juveniles residing in the area. Surf smelt in offshore areas are known to consume a wide variety of Crustacea, various marine worms, insects, comb jellies and larval fishes (Hart, 1973).

The surf smelt of British Columbia supports moderate commercial gill net and purse seine fisheries. Yearly landings have fluctuated between 13,000 and 102,000 pounds (Hart, 1973).

B5.12 THREESPINE STICKLEBACK - *Gasterosteus aculeatus*

The threespine stickleback is a highly adaptable species found in fresh water, brackish water, and open ocean (Hart, 1973). They are distributed along the Pacific coast of North America from Baja California to the Bering Sea and on the Asiatic coast as far south as Korea and Japan (Hart, 1973). The species is also abundant on the Atlantic coast of North America and in Europe (Whitworth et al, 1968; Hart, 1973; Scott and Crossman, 1973). It is commonly found in brackish waters of harbours where it schools in eelgrass and around wharves (Hart, 1973). According to Scott and Crossman (1973), the threespine stickleback may be represented by two subspecies - *G. aculeatus trachurus* (the marine form) and *G. aculeatus leiurus* (the freshwater form). *Leiurus* never leaves fresh water but *trachurus* migrates from the marine environment to spawn in fresh water in the spring.

The breeding habits of this nest-building species have been well documented in the behavioural literature and on film. The male builds a nest which it guards subsequent to spawning. The male also guards the young fish after hatching (Scott and Crossman, 1973). Spawning generally takes place in fresh water in June or July (Scott and Crossman, 1973), but some spawning has been reported in salt water (Hart, 1973), although egg development is adversely affected by salt water. Some breeding takes place throughout the summer months (April to September in the Cowichan River, British Columbia) according to Scott and Crossman (1973). Newly hatched larvae range from 4.2 to 5 mm in length, and at the end of the first summer they range from 15-33 mm in total length (Scott and Crossman, 1973). The fish mature during their first year and probably do not exceed 3.5 years in age (Scott and Crossman, 1973).

The threespine stickleback feeds on a wide variety of animal foods. The diet of adults in the southern Strait of Georgia was mainly copepods in late spring and early autumn (Hart, 1973), but many other foods are commonly consumed including eggs and fry of fish, amphipods, euphausids, decapod larvae, barnacle larvae, ostracods, cladocerans, clam larvae, worms, and aquatic insects (Scott and Crossman, 1973; Hart, 1973). The stickleback may consume the following fish species: herring, bigeye, sand lance, searchers, rockfish and young stickleback (Scott and Crossman, 1973; Hart, 1973). Stickleback are also common prey for fish eating birds, fur seals, and various piscivorous fishes such as salmon and trout (Scott and Crossman, 1973; Hart, 1973).

In a recent study (Department of Environment, Fisheries and Marine Service, 1975), threespine stickleback was the most abundant species collected in the Fraser River and was the fourth most abundant species on Roberts Bank. It is very likely that the marine form of threespine stickleback (*trachurus*) uses the intercauseway area as a

feeding area at times other than the breeding season. Because of the relatively high salinity in this area it is unlikely that any significant breeding of stickleback takes place here. Since the species is rather abundant it probably serves as an important food resource for salmonids such as coho and chinook salmon which are also found in this area.

B5.13 SHINER PERCH - *Cymatogaster aggregata*

The shiner perch is a small surfperch found along the Pacific coast of North America from Baja California to southern Alaska (Hart, 1973). In summer they are common in the shallow waters of British Columbia, but in winter they are found in deeper waters down to a record of 128 m (Hart, 1973).

The breeding season in British Columbia for this live-bearer is from April to July, but gestation does not begin until November or December when the sperm penetrate the ovary (Hart, 1973). The young are generally born in June or July, but may be born as late as August or as early as May. These young range from 5.6 to 7.8 centimeters long at birth (Hart, 1973), which is approximately half the maximum adult size of about 15 centimeters. Males are mature at birth but females do not breed until they are approximately 2 years old (Hart, 1973).

Young shiner perch feed primarily on copepods, but older fish may consume mussels, algae or barnacle appendages (Hart, 1973). The shiner perch has little commercial value because of its small size; however, according to Hart (1973) they are used as fresh fish in Canada and as bait in California.

Since the shiner perch is a common inshore resident during spring and summer it is not surprising that in a recent study of the

Fisheries Resources of the Fraser River estuary (Department of Environment, Fisheries and Marine Service, 1975), the shiner perch was one of the species commonly collected. On Roberts Bank, shiner perch was the third most abundant fish species collected. Young of shiner perch could possibly serve as food for the larger juvenile salmonids such as chinook and coho salmon which occupy the area concurrently but this has not been definitely established. Because of the relatively large size of newborn shiner perch, these fish may be less vulnerable to predation by juvenile salmon than such fish as sand lance and herring.

B5.14 PACIFIC SAND LANCE - *Ammodytes hexapterus*

The Pacific sand lance is widely distributed in the North Pacific and beyond (Hart, 1973), occurring all along the coast of Asia from the Sea of Japan north to the Chukchee Sea and in North America from southern California to Alaska and across Arctic Canada to the Hudson Bay. The sand lance is sometimes found offshore, but at other times they may be found either in large schools swimming against the tidal currents of channels or they may even bury themselves almost completely in beach sand at other times (Hart, 1973). They are abundant in the surface waters off the Fraser River outlet in early summer; when larvae, post-larvae and adults may be found (Hart, 1973). Sand lance are reported to use the protection of eelgrass beds for spawning (Hoos and Packman, 1974). The sand land feed mainly on copepods, copepod eggs and nauplii (Hart, 1973).

The sand lance is an important food source for such piscivorous fish as chinook and coho salmon (Hart, 1973; Scott and Crossman, 1973) which also occupy the areas of Sturgeon and Roberts Banks. On Sturgeon Bank the Pacific sand lance was the third most abundant fish species captured and on Roberts Bank it ranked sixth in abundance

(Department of Environment, Fisheries and Marine Service, 1975). It is likely that sand lance use the eelgrass habitat in the intercauseway area as a spawning area.

B5.15 STARRY FLOUNDER - *Platichthys stellatus*

The starry flounder is a common flatfish found on the Pacific coast of North America from southern California to the Chukchee Sea. In the western Pacific Ocean they are found as far south as Korea (Hart, 1973). Starry flounder are commonly found in shallow water along the entire coast of British Columbia (Hart, 1973).

Spawning takes place in shallow water in February and April in Puget Sound and British Columbia (Hart, 1973) at ages of II or more for males and III or more for females. Starry flounder eggs are non-adhesive and slightly lighter than sea water (Hart, 1973) which implies that they are basically planktonic prior to hatching. Larval and juvenile starry flounder are reported to consume primarily copepods, copepod nauplii, barnacle larvae and cladocerans and amphipods, while older fish consume crabs, shrimp, worms, clams, other molluscs, small fishes, and starfish (Hart, 1973; Haertel and Osterberg, 1967). Feeding all but ceases during the winter when growth also stops (Haertel and Osterberg, 1967; Hart, 1973). The starry flounder is noted for its tolerance of low salinities with young occurring in the Fraser River, the Columbia River, and the Salinas River in California (Hart, 1973; Haertel and Osterberg, 1967). Juvenile starry flounder appeared to use the upper estuary of the Columbia River as a nursery ground, remaining there from 2 to 2-1/2 years (Haertel and Osterberg, 1967). Hoos and Packman (1974) noted that several studies had found the starry flounder further upriver than any other marine fishes commonly occurring in the Fraser River system.

In a recent study of the Fraser River estuary, starry flounder ranked fourth and fifth in abundance on Sturgeon Bank and Roberts Bank respectively (Department of Environment, Fisheries and Marine Service, 1975). Starry flounder was one of the most abundant species taken in the Fraser River below the Port Mann Bridge. Young starry flounder may potentially serve as prey for salmon on Roberts Bank, but this has not been established.

Landings of one half million pounds (227 metric tons) are martketed annually although the starry flounder is not highly regarded as a commercial species in British Columbia (Hart, 1973).

B5.16 SUMMARY

Table B20 summarizes the habitats per life stage for each of the species discussed above. Pacific herring, *Clupea harengus*, are the single most important species in the area on a basis of numbers and as a food source for chinook and coho salmon. Sport fishing, in recreational rather than biological terms, is discussed in Appendix C.

B5.17 THE FISH INTERRELATIONSHIPS OF ROBERTS BANK

The Roberts Bank area serves as a spawning or rearing area for a number of important fish species. Pacific herring use the eelgrass beds along the Banks, particularly in the intercausway area, as a spawning substrate, with spawning taking place in late winter - February or March. The eggs hatch in the spring and the larvae begin to feed on the invertebrate found associated with the eelgrass habitat. Young herring were the most abundant fish species found in the intercauseway area in 1973 (Department of Environment, Fisheries and Marine Service, 1975), and represented 96% of all the fish caught on Roberts Bank. Pacific

TABLE B20. FISH HABITAT SUMMARY

Species	Life Stage
Pacific Herring (*Clupea harengus pallasi*)	Egg/Embryo - inshore marine area of reduced salinity; 4-10°C; on aquatic plants (eelgrass) and occasional rocks and pilings; late winter, early spring
	Larvae/Alevin - inshore marine in the vicinity of spawning; early spring
	Fry/Parr - inshore marine in the vicinity of spawning; spring
	Smolt - life stage not applicable to this species
	Juvenile - bays and inlets near kelp beds in summer; offshore banks from fall to maturity at 3 to 4 years
	Reproductive Adult - offshore banks for feeding, summer-fall-winter; spawn inshore near or on aquatic plants, late winter, early spring
Pink Salmon (*Oncorhynchus gorbuscha*)	Egg/Embryo - freshwater rivers and streams, subgravel; fall (Sept.-Oct.) through winter (Dec.-Feb.)
	Larvae/Alevin - freshwater rivers and streams; subgravel; spring (Feb.-May)
	Fry/Parr - life stage missing or very brief (April, May)
	Smolt - freshwater rivers and streams through estuarine waters to marine habitat; April and May, immediately after emergence; migrate at 4-5°C
	Juvenile - inshore water near mouth of river for several weeks or months, migration to deeper open sea waters by September; remain at sea until maturity at age two
	Reproductive Adult - migrate from open sea to freshwater rivers and streams for spawning (Sept.-Oct., second year of life)

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Chum Salmon (*O. keta*)	Egg/Embryo - freshwater rivers and streams, subgravel; fall and winter (October on)
	Larvae/Alevin - freshwater rivers and streams, subgravel; winter-early spring, (emergence in March)
	Fry/Parr - very brief stage after emergence (March)
	Smolt - freshwater rivers and streams through estuarine waters to marine habitat; emigration begins in mid March, may last until May
	Juvenile - coastal waters adjacent to natural streams till mid-August; by mid-August migration to high seas begins; ocean waters till age 4 or 5 when maturation occurs
	Reproductive Adult - migrate from open seas to coastal waters by June to November of 4th or 5th year of life; freshwater entered soon after arriving at coastal water (Aug. to mid-Jan.); two peak runs: mid-Oct. to early Nov. and mid-Nov. to early Dec.
Coho Salmon (*O. kisutch*)	Egg/Embryo - freshwater, subgravel in streams and some larger rivers (to a lesser extent); fall and winter (Sept. on)
	Larvae/Alevin - freshwater rivers and streams, subgravel; winter and early spring (emergence between early March and late July)
	Fry/Parr - freshwater rivers and streams for approximately one year
	Smolt - freshwater rivers and streams through estuarine waters to marine habitat; migration to salt water begins in March or April; arrive at mouth in May

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Coho Salmon (Cont'd)	Juvenile - lower river, estuarine and inshore areas through spring and summer; migration to open sea in fall; ocean water until 3 or 4 years old when maturation occurs (at age two for some males)
	Reproductive Adult - migrate from open sea south along Alaskan and B.C. coast; enter main stream of Fraser between July and November
Sockeye Salmon (*O. nerka*)	Egg/Embryo - freshwater streams, subgravel; fall and winter (as early as July) incubation from 50 days to 5 months
	Larvae/Alevin - freshwater streams, subgravel; spring (Feb.-Mar.-April) 3-5 weeks duration
	Fry/Parr - migrate to lakes or occasionally rivers without lakes, found along shoreline of lakes initially before movement to deeper water after a few weeks; this stage commonly lasts one year until spring following hatching
	Smolt - lake water till temperature ranges from 4-7^{o}C at surface, then downstream through streams and rivers to estuarine and marine water; migration at 3-4 km/day; spring of second year of life, leaves Fraser by early May
	Juvenile - inshore areas during late spring-early summer, later offshore; statistics suggest fish leave vicinity of Fraser by mid-late May and are not taken on adjacent banks; fish remain at sea for more than two years when maturation occurs
	Reproductive Adult - mature adults begin an inshore migration during summer of the fourth year; a pre-spawning migration occurs in the river during July for early run and August or Sept. for later run; spawning occurs in the fall in the tributaries or outlet streams of lakes

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Chinook Salmon (*O. tshawytscha*)	Egg/Embryo - freshwater streams subgravel, eggs spawned July-Nov. (several runs); hatching several months later in the spring
	Larvae/Alevin - freshwater streams, subgravel; stage lasts 2-3 weeks (emergence Jan.-March)
	Fry/Parr - freshwater streams and rivers; variable stage duration; usually migration begins soon after emergence, but freshwater stage may last one year or more
	Smolt - freshwater streams and rivers to estuarine to marine water; emigration occurs in the spring with the young appearing off the mouth of the Fraser in April
	Juvenile - juveniles appear to remain inshore on the banks during the first summer outside the river; later go to open ocean; probably leave in fall and spend 2-3 years at sea until maturity
	Reproductive Adult - mature fish return at age 4 or 5, appear off the mouth of the Fraser as early as Jan., with maximum in Aug./Sept.; spawning is generally in the fall
Cutthroat Trout (*Salmo clarki*)	Egg/Embryo - freshwater streams, subgravel; spawning Nov.-May; hatch in spring; 6-7 weeks till hatch
	Larvae/Alevin - freshwater streams, subgravel; spring, one-two 233ks till emergence as early as April
	Fry/Parr - after emergence residence in fresh water varies with migration occurring during 1st, 2nd or 3rd year of life or not at all in some populations

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Cutthroat Trout Cont'd	Smolt - freshwater streams to rivers to estuarine or brackish waters; usually migration occurs in the spring
	Juvenile - coastal form remains in the influence of the river - stays in estuary moving into streams in spring to feed on migrating salmon; remains at sea for one or more years
	Reproductive Adult - mature fish return to natal stream in late autumn and early winter; some repeat spawning may occur; average age at spawning 2-4 years
Steelhead (*Salmo gairdneri*)	Egg/Embryo - freshwater stream, subgravel; mid-April to May spawning and 4-7 weeks to hatch
	Larvae/Alevin - freshwater stream, subgravel; late spring-summer; 3-7 days to absorb yolk sac; emergence from mid-June to mid-August
	Fry/Parr - from 1-4 years (fry generally 2 years) spent in freshwater streams or lakes
	Smolt - freshwater streams, lakes through estuary to sea; migration generally during spring
	Juvenile - the young are found in the less saline waters of the Strait of Georgia off the outlet of the Fraser; they remain at sea (and may make extensive migrations) for various periods, returning to spawn after 1-4 years at sea
	Reproductive Adult - mature adults return to spawn at ages ranging from about 3 years to 7 years with repeat spawning common
Dolly Varden (*Salvelinus malma*)	Egg/Embryo - spawning September through early November in streams of moderate current, medium to large gravel, subgravel; freshwater hatching in March-April (4-1/2 months after spawning)

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Dolly Varden Cont'd	Larvae/Alevin - freshwater, subgravel; about three weeks in gravel until emergence in April
	Fry/Parr - freshwater streams at 3 or 4 years in anadromous population
	Smolt - freshwater streams and rivers, estuaries and sea at age 3-4 years; migration May to early June
	Juvenile - variable time at sea; only short distances from river mouth; back into rivers from May to Dec., usually mid-July to September
	Reproductive Adult - sexual maturity at 3-6 years after which mature adults return to river yearly to spawn
Surf Smelt (*Hypomesus pretiosus*)	Egg/Embryo - spawning on beaches, adhesive eggs; spawning in most months of year; in summer 10-11 days to hatch, longer in winter
	Larvae/Alevin - not known
	Fry/Parr - not known
	Smolt - not applicable
	Juvenile - life history not well known; found in offshore areas as well as inshore
	Reproductive Adult - age determination uncertain, may live to age 3 years; individuals may spawn several times
Threespine Stickleback (*Gasterosteus aculeatus trachurus*)	Egg/Embryo - breeding in fresh water in spring and summer; hatch about 7 days
	Larvae/Alevin - fresh water nest until able to care for selves (unknown time)

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Threespine Stickleback Cont'd	Fry/Parr - freshwater streams first year of life (summer)
	Smolt - freshwater streams, brackish or marine environment first year of life (summer or fall)
	Juvenile - brackish water areas prior to sexual maturation
	Reproductive Adult - sexual maturity occurs during the first year of life, after which breeding migration annually to freshwater streams, 3-5 years maximum age; other time in brackish water about eelgrass
Shiner Perch (*Cymatogaster aggregata*)	Egg/Embryo - live bearer
	Larvae/Alevin - live bearer
	Fry/Parr - live bearer
	Smolt - not applicable
	Juvenile - born in June or July in shallow inshore waters; males are mature at birth but females remain juveniles for two years; in summer found in shallow water, in winter move off to deep water
	Reproductive Adult - distribution inshore in summer, offshore in winter
Pacific Sand Lance (*Ammodytes hexapterus*)	Egg/Embryo - spawning occurs in eelgrass beds, probably in spring
	Larvae/Alevin - found in surface waters off Fraser outlet in early summer
	Fry/Parr - same as Larvae/Alevin
	Smolt - not applicable
	Juvenile - same as Larvae/Alevin

TABLE B20. FISH HABITAT SUMMARY CONT'D

Species	Life Stage
Pacific Sand Lance Cont'd	Reproductive Adult - sometimes found offshore, other times found inshore in channels and so forth
Starry Flounder (*Platichthys stellatus*)	Egg/Embryo - February to April spawning in shallow water (time to hatching not known); eggs planktonic (adhesive and lighter than water)
	Larvae/Alevin - symetrical (presumably in shallow water)
	Fry/Parr - transformation at 10.5 mm to asymmetry during first year of life
	Smolt - not applicable
	Juvenile - found in estuarine waters; enters mouths of rivers and may remain 2 to 2-1/2 years
	Reproductive Adult - males mature at age 2 or more, females at age 3 or more

herring may clearly be considered a dominant factor in the fish community of Roberts Bank.

Soon after the herring hatch, they are joined on the banks by anadromous chinook salmon juveniles and coho salmon juveniles. Other salmon species are much less abundant here and coho are somewhat piscivorous, consuming young herring and other fishes as well as invertebrates. However, in the intercauseway area chinook and coho are much more piscivorous than elsewhere on the banks. In the intercauseway area, larval and juvenile fish comprised 92.7% of the juvenile chinook diet and 99.6% of the coho diet (Department of Environment, Fisheries and Marine Service, 1975). Undoubtedly, the fact that herring are exceptionally abundant in this area contributes substantially to the production of these young salmon. It would seem that the biological production of those portions of the chinook salmon and coho salmon stocks residing in the intercauseway area is directly dependent upon the production of juvenile herring, and further, that the production of juvenile herring is dependent upon the availability of eelgrass spawning habitat.

Other species using this intertidal and subtidal habitat are the threespine stickleback, shiner perch, starry flounder, Pacific sand lance and surf smelt. These species are common inshore fishes throughout the Pacific northwest.

The threespine stickleback is anadromous, spawning in fresh water from April to September (primarily June or July). They commonly feed on planktonic invertebrates, but they may also consume some benthic invertebrates or fish eggs and larvae. The stickleback may also serve as prey for young salmon. The stickleback was the fourth most frquently caught fish species on Roberts Bank; however, more than 40 times as many herring were captured on Roberts Bank.

The shiner perch is a ubiquitous fish along the Pacific coast, and was the third most frequently captured fish on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975). Shiner perch are live bearers and the young fish are quite large at birth (5.6 to 7.8 centimeters), thus they are probably not an important food source for the juvenile salmonids on Roberts Bank. The young fish are known to feed on zooplankton, but adults may consume mussels, algae or barnacle appendages. Shiner perch are only found in inshore waters during the summer.

The Pacific sand lance was the sixth most frequently captured fish on Roberts Bank (Department of Environment, Fisheries and Marine Service, 1975). Its life history is not well known, but it is reported to use eelgrass beds as spawning habitat. The sand lance feed primarily on small zooplankton, and they are, in turn, fed upon by larger fishes such as chinook and coho salmon.

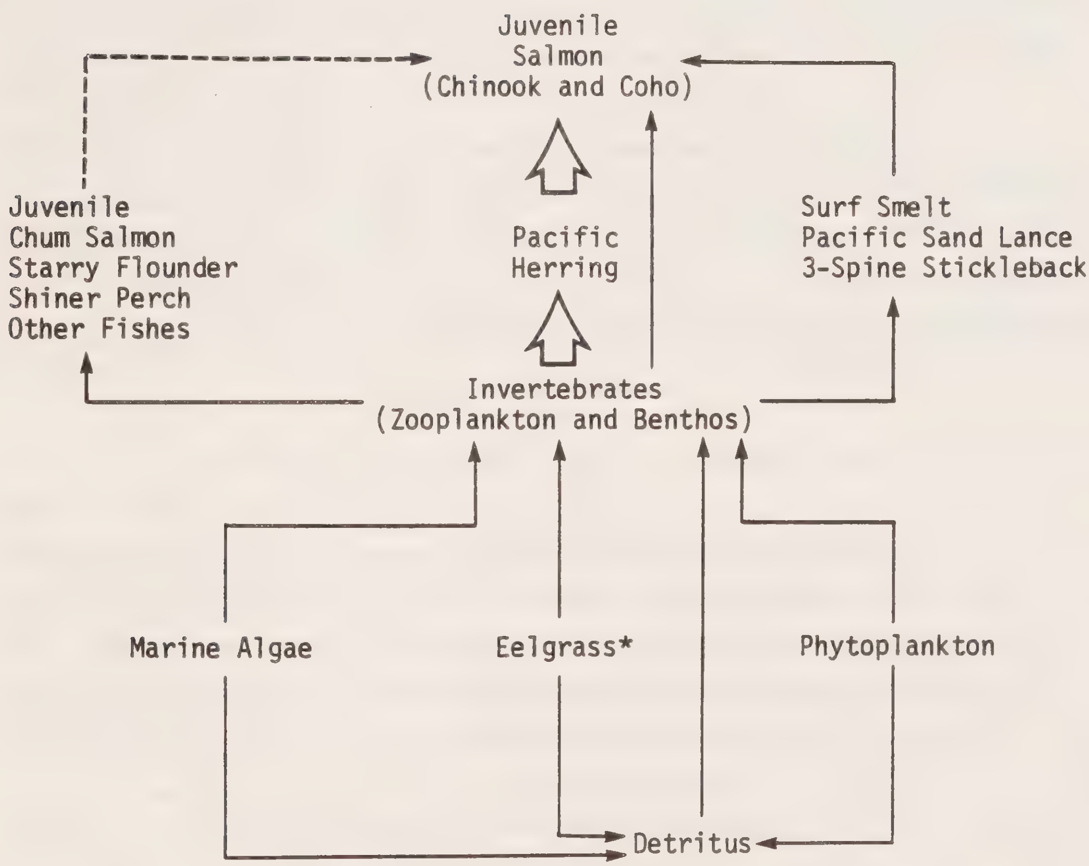
The surf smelt is abundant throughout British Columbia and on Roberts Bank it was the seventh most frequently caught fish (Department of Environment, Fisheries and Marine Service, 1975). The surf smelt spawn on protected beaches in most months of the year. The life history of this species is not well known, but it is known to consume planktonic and benthic invertebrates, as well as larval fishes. Surf smelt are probably consumed to some extent by the chinook and coho salmon which utilize Roberts Bank. Additionally, this species has some commercial value.

The starry flounder is a common flatfish found in inshore waters, and this species was the fifth most frequently captured fish on Roberts Bank (Department of Environment, Fisheries and Marine Service,

1975). Spawning takes place in shallow water between February and April. The young flounder feed on zooplankton, but the adults consume a wide variety of benthic and planktonic invertebrates and some small fishes. Starry flounder are noted for their tolerance of low salinities and they may use coastal rivers as nursery grounds. Starry flounder juveniles may contribute somewhat to the food requirements of juvenile salmon, but this has not been confirmed. Considering the relative abundance of starry flounder and Pacific herring, it is not likely that starry flounder contribute much to the salmon diet in the intercauseway area.

As a pictorial representation of the organization of the fish community, a food web has been prepared which illustrates the primary pathways of energy flow which are believed to exist in the intercauseway area (Figure B 7). This food web is not meant to be an exact duplication of the actual energy relations on Roberts Bank; however, it does provide a framework upon which one can build a reasonable impact assessment.

FIGURE B7 A SIMPLIFIED FOOD WEB ILLUSTRATING THE PRIMARY ENERGY PATHWAYS IN THE INTERCAUSEWAY AREA OF ROBERTS BANK



*Important spawning habitat for Pacific herring and Pacific sand lance

B6.0 AVIFAUNA

The Fraser River estuary is well known for its concentrations of birds, particularly waterfowl. Consequently, a large amount of published and unpublished information has been generated by parties interested in waterfowl management and conservation. Nonetheless, the area around the Roberts Bank Westshore Terminal has received less attention than areas such as Boundary Bay and Westham Island, where concentrations of birds historically have been greater.

While large numbers of birds of many ecological groups utilize the Fraser River delta, certain groups are of greater importance owing to their sensitivity to disturbance, population status, economic importance and local or international interest. These groups will be considered in the following discussion of the Fraser River delta and the port expansion area itself.

B6.1 FIELD PROGRAM

In order to add site-specific quantitative information to the qualitative assessment of avifauna in the Roberts Bank area, a field study was conducted between April 22 and May 10, 1977. Literature review demonstrated this time period represents a comparatively unimportant phase in the year-round cycle of habitat use by birds in the area. This is not of great consequence, because the impact evaluation will be based mainly on habitat alteration. If the proposed expansion significantly alters habitat, it is reasonable to assume that certain bird groups will be at least temporarily affected.

The study area was visited a total of six times between April 22 and May 10, 1977. Data was collected on species, number, location and behaviour of birds on either side of the causeway. To compensate

for varying tide conditions, four surveys were conducted at high tide (high and falling) and two at low tide (low and rising). Birds were identified and counted with the aid of a 20-45 power spotting scope and 7x35 binoculars.

A total of eight survey areas were examined from five observation points during each survey (Figure B8). Three observation points, 2.96 km apart, were located at power poles (numbers 150, 180 and 210) on the causeway, and another two on either side of the coal loading area. The causeway sites facilitated bird observation within the area of present port activities and potential expansion, as well as in the landward area. Observation points on the coal loading area were established to document the occurrence of pelagic and other bird species in the immediate vicinity of dock activities. It was not possible to locate an observation point at the actual coal loading dock because of the presence of ships.

Each of the eight survey areas was divided into ten zones based on visual estimation of distances. Ease of distance estimation dictated the area and shape of each zone, and not any habitat-related phenomena. The dimensions of each zone are illustrated in Figure B9. Bird sightings were related to a position within particular zones. This site-specific data should be useful in terms of examining the relationship between bird sightings and habitat characteristics of the area.

B6.2 AVIFAUNA DISTRIBUTION IN THE STUDY AREA

To examine more accurately the locations of birds, each observation area is discussed separately.

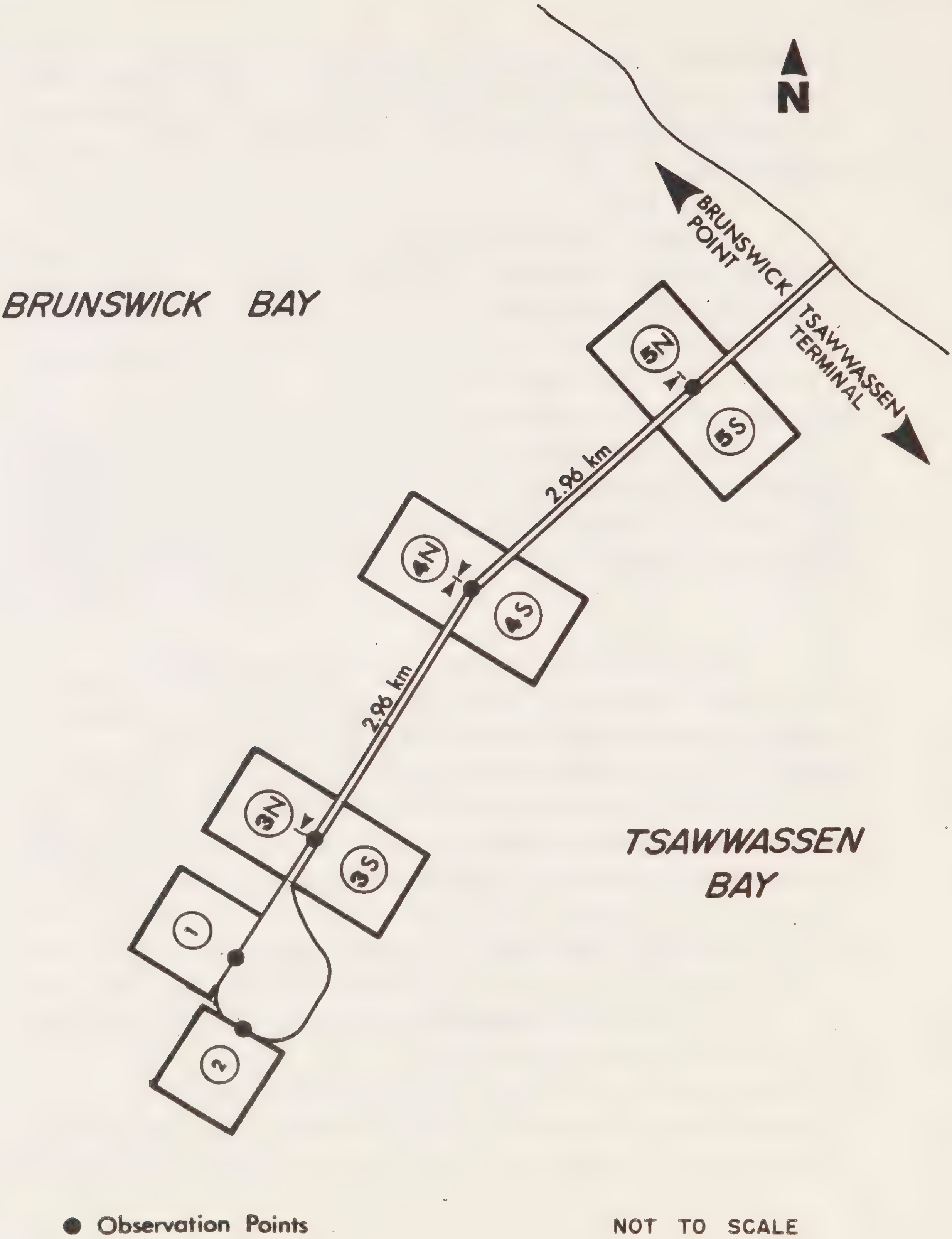


FIGURE B-8 Illustration of observation areas

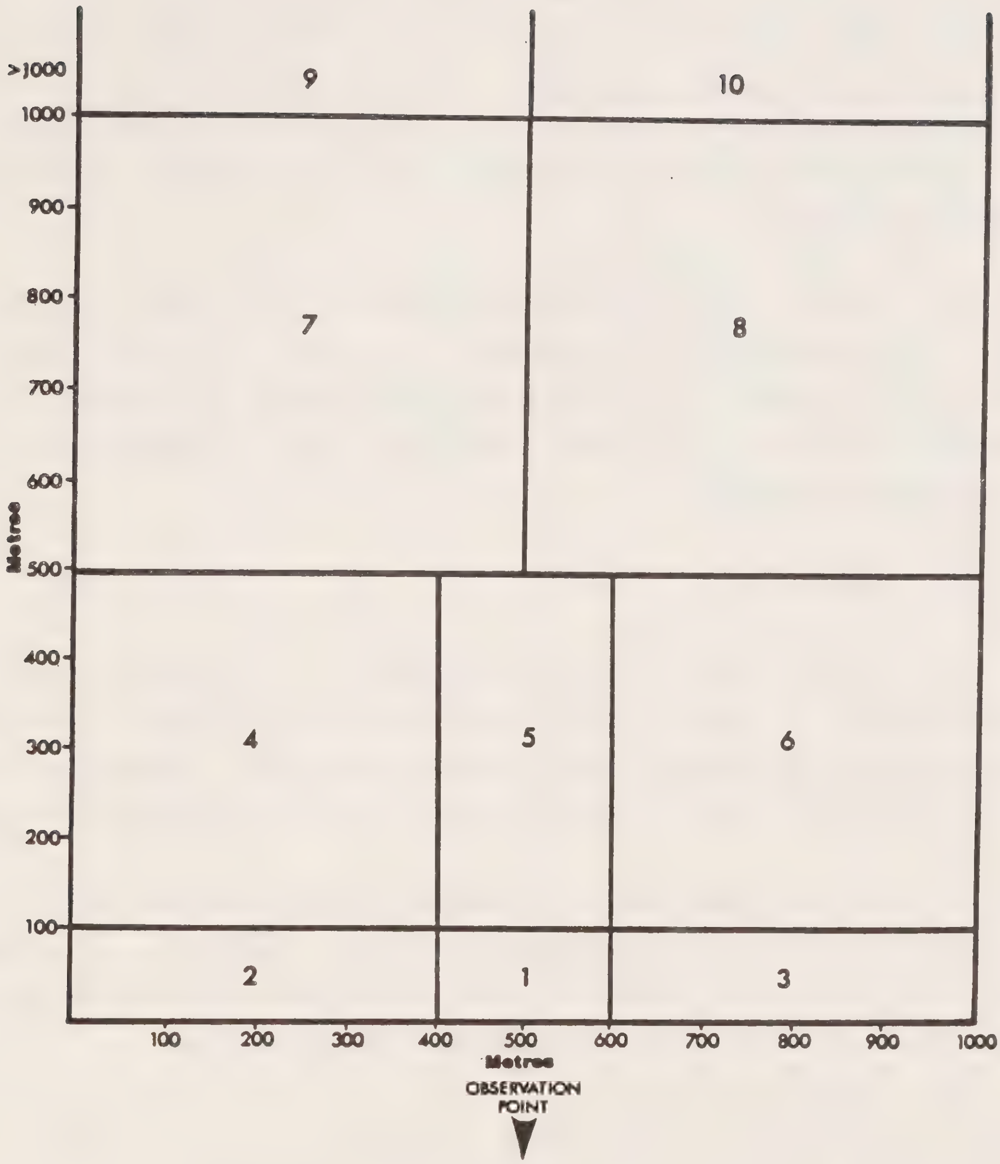


FIGURE B-9 Area diagram and dimensions

Area 1

More birds frequented this area at high rather than low tide (Table B21), a situation which was repeated in all areas except 4S. At high tide, most birds were observed in Zones 10 (36 percent), 9 (33 percent) and 8 (15 percent) (Table B22). Of these, loons, grebes and cormorants comprised the greatest percentage of birds for the area (79), with diving ducks (10 percent) and gulls and terns occurring in smaller numbers (Table B22).

At low tide, the majority of birds were in Zones 7 (39 percent), 8 (38 percent) and 5 (13 percent) (Table B22). Here too, loons, grebes and cormorants occurred in the largest numbers (61 percent), while gulls and terns (18 percent) and diving ducks (16 percent) were not as well represented.

Area 2

At high tide, Zones 1 (30 percent), 2 (18 percent), 3 (13 percent) and 10 (13 percent) contained the majority of birds (Table B23). Gulls and terns were most common (67 percent) but loons, grebes and cormorants (18 percent) and alcids (14 percent) were also present (Table B23).

At low tide, Zones 7 (70 percent), 1 (21 percent) and 4 (6 percent) contained the greatest numbers of birds (Table B23). Of these birds, diving ducks (43 percent), loons, grebes and cormorants (41 percent) and gulls and terns (10 percent) were in the majority.

Area 3N

Zones 9 (38 percent), 8 (23 percent) and 10 (23 percent) contained the majority of birds at high tide (Table B24). Once again, loons,

TABLE 1 OBSERVATION POINTS (AREA VALUES AND PERCENT OF GROUP TOTALS)

SPECIES	TIDE	1	2	3 North	3 South	4 North	4 South	5 North	5 South	Group % Total Total Number
LOONS, GREBES, CORMORANTS	LOW & RISING	159(65)	29(12)	4(2)	43(17)	11(4)	-	-	-	246(5)
	HIGH & FALLING	476(47)	55(5)	206(21)	50(5)	171(17)	36(4)	10(1)	-	1,004(3)
GREAT BLUE HERON	LOW & RISING	-	-	-	-	12(36)	20(61)	-	1(3)	33(1)
	HIGH & FALLING	-	-	-	-	4(3)	3(2)	124(84)	16(11)	147(<1)
BRANT	LOW & RISING	6(2)	-	6(2)	-	66(22)	219(70)	10(3)	-	298(6)
	HIGH & FALLING	-	-	-	-	570(16)	1,770(50)	512(14)	700(20)	3,552(9)
DABBLING DUCKS	LOW & RISING	-	-	-	-	192(76)	60(24)	-	-	252(5)
	HIGH & FALLING	-	-	-	-	-	107(34)	204(66)	-	311(1)
DIVING DUCKS	LOW & RISING	41(7)	30(5)	49(9)	59(10)	123(22)	265(47)	-	-	1,530(12)
	HIGH & FALLING	59(3)	2(<1)	187(9)	104(5)	170(8)	980(46)	647(30)	2(<1)	2,151(6)
UNIDENTIFIED DUCKS	LOW & RISING	-	-	-	-	30(2)	1,500(98)	-	-	1,530(33)
	HIGH & FALLING	-	-	-	-	-	2,000(100)	-	-	2,000(5)
RAPTORS	LOW & RISING	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	-	-	-	-	-	-	2(67)	1(33)	3(<1)
SHORE BIRDS	LOW & RISING	-	-	-	-	40(3)	1,200(92)	59(5)	-	1,299(28)
	HIGH & FALLING	-	-	-	-	1,700(6)	-	25,025(92)	499(2)	27,224(71)
GULLS AND TERNS	LOW & RISING	47(11)	7(2)	31(8)	-	103(25)	175(43)	24(6)	24(6)	411(9)
	HIGH & FALLING	43(2)	206(10)	159(8)	215(11)	61(3)	47(2)	1,051(53)	188(10)	1,970(5)
ALCIDS	LOW & RISING	2(20)	4(40)	-	4(40)	-	-	-	-	10(<1)
	HIGH & FALLING	23(27)	44(52)	13(15)	5(6)	-	-	-	-	85(<1)
PASSERINES	LOW & RISING	6(46)	-	-	5(38)	-	-	-	2(15)	13(<1)
	HIGH & FALLING	1(5)	-	-	10(48)	2(10)	5(24)	-	3(14)	21(<1)
AREA TOTAL AND % TOTAL NUMBER	LOW & RISING	261(6)	70(2)	90(2)	111(2)	577(12)	3,430(74)	89(2)	27(1)	4,659
	HIGH & FALLING	602(2)	307(1)	565(1)	384(1)	2,678(7)	4,948(13)	27,575(72)	1,409(4)	38,468

TABLE 2 OBSERVATION POINT 1

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group % Area Total Total
LOONS, GREBES, CORMORANTS	LOW & RISING	4(3)			1(1)	1(1)	-	80(50)	73(46)	-	-	159(61)
	HIGH & FALLING	8(2)	1(<1)	1(<1)	-	5(1)	1(<1)	23(5)	57(12)	195(41)	185(39)	476(79)
GREAT BLUE HERON	LOW & RISING											- -
	HIGH & FALLING											- -
BRANT	LOW & RISING					6(100)						6(2)
	HIGH & FALLING											- -
DABBLING DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
DIVING DUCKS	LOW & RISING	5(12)	-	-	4(10)	25(61)	6(15)	1(2)	-	-	-	41(16)
	HIGH & FALLING	-	-	-	2(3)	-	15(25)	-	31(53)	-	11(19)	59(10)
UNIDENTIFIED DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
RAPTORS	LOW & RISING											- -
	HIGH & FALLING											- -
SHORE BIRDS	LOW & RISING											- -
	HIGH & FALLING											- -
GULLS AND TERNS	LOW & RISING	-	2(4)	-	-	-	-	20(43)	25(53)	-	-	47(18)
	HIGH & FALLING	21(49)	-	-	-	-	-	2(5)	-	-	20(47)	43(7)
ALCIDS	LOW & RISING	-	-	-	-	2(100)	-	-	-	-	-	2(1)
	HIGH & FALLING	3(13)	9(39)	3(13)	3(13)	2(9)	-	-	2(9)	1(4)	-	23(4)
PASSERINES	LOW & RISING	6(100)	-	-	-	-	-	-	-	-	-	6(2)
	HIGH & FALLING	1(100)	-	-	-	-	-	-	-	-	-	1(<1)
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	15(6)	2(1)	-	5(2)	34(13)	6(2)	101(39)	98(38)	-	-	261
	HIGH & FALLING	33(5)	10(2)	4(1)	5(1)	7(1)	16(3)	25(4)	90(15)	196(33)	216(36)	602

TABLE 3 OBSERVATION POINT 2

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group Total % Area Total
LOONS, GREBES, CORMORANTS	LOW & RISING	7(24)	1(3)	-	2(7)	-	-	19(66)	-	-	-	29(41)
	HIGH & FALLING	2(4)	2(4)	1(2)	2(4)	1(2)	3(5)	1(2)	10(18)	8(15)	25(45)	55(18)
GREAT BLUE HERON	LOW & RISING											- -
	HIGH & FALLING											- -
BRANT	LOW & RISING											- -
	HIGH & FALLING											- -
DABBLING DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
DIVING DUCKS	LOW & RISING	2(7)	-	-	-	-	1(3)	27(90)	-	-	-	30(43)
	HIGH & FALLING	-	2(100)	-	-	-	-	-	-	-	-	2(1)
UNIDENTIFIED DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
RAPTORS	LOW & RISING											- -
	HIGH & FALLING											- -
SHORE BIRDS	LOW & RISING											- -
	HIGH & FALLING											- -
GULLS AND TERNS	LOW & RISING	5(71)	-	-	2(29)	-	-	-	-	-	-	7(10)
	HIGH & FALLING	86(42)	48(23)	38(18)	6(3)	-	5(2)	-	17(8)	-	6(3)	206(67)
ALCIDS	LOW & RISING	1(25)	-	-	-	-	-	3(75)	-	-	-	4(6)
	HIGH & FALLING	4(9)	2(5)	-	2(5)	-	4(9)	8(18)	4(9)	12(27)	8(18)	44(14)
PASSERINES	LOW & RISING											- -
	HIGH & FALLING											- -
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	15(21)	1(1)	-	4(6)	-	-	49(70)	-	-	-	70
	HIGH & FALLING	92(30)	54(18)	39(13)	10(3)	1(<1)	12(4)	9(3)	31(10)	20(7)	39(13)	307

TABLE 4 OBSERVATION POINT 3N

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group % Area Total Total
LOONS, GREBES, CORMORANTS	LOW & RISING		-		-	3(75)	-	1(25)	-	-	-	4(4)
	HIGH & FALLING		2(1)		15(7)	3(1)	4(2)	35(17)	48(23)	96(47)	3(1)	206(36)
GREAT BLUE HERON	LOW & RISING											
	HIGH & FALLING											
BRANT	LOW & RISING				6(100)							6(7)
	HIGH & FALLING				-							-
DABBLING DUCKS	LOW & RISING											
	HIGH & FALLING											
DIVING DUCKS	LOW & RISING	16(33)		-	2(4)	1(2)	-	4(8)	21(43)	-	5(10)	49(54)
	HIGH & FALLING	-		2(1)	-	-	2(1)	12(6)	83(44)	44(24)	44(24)	187(33)
UNIDENTIFIED DUCKS	LOW & RISING											
	HIGH & FALLING											
RAPTORS	LOW & RISING											
	HIGH & FALLING											
SHORE BIRDS	LOW & RISING											
	HIGH & FALLING											
GULLS AND TERNS	LOW & RISING	1(3)									30(97)	31(34)
	HIGH & FALLING	3(2)								75(47)	81(51)	159(28)
ALCIDS	LOW & RISING	-	-		-			-			-	-
	HIGH & FALLING	2(15)	1(18)		2(15)			7(54)			1(8)	13(2)
PASSERINES	LOW & RISING											
	HIGH & FALLING											
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	17(19)	-	-	8(9)	4(4)	-	5(6)	21(23)	-	35(39)	90
	HIGH & FALLING	5(1)	3(1)	2(4)	17(3)	3(1)	6(1)	54(10)	131(23)	215(38)	129(23)	565

grebes and cormorants were most common (36 percent) but diving ducks (33 percent) and gulls and terns (28 percent) were also well represented. At low tide, birds were found in similar zones: 10 (39 percent), 8 (21 percent) and 1 (19 percent). Diving ducks were most prevalent (54 percent) but gulls and terns (34 percent) and a few brant (7 percent) were also observed (Table B24).

Area 3S

At high tide, most birds were located near the causewasy in Zones 1 (37 percent) and 4 (23 percent) but some were farther away in Zone 8 (20 percent) (Table B25). Gulls and terns comprised the greatest percentage of birds in the area (56), but diving ducks (27) and loons, grebes and cormorants were common. At low tide, birds were spread evenly through most zones but the majority were in 7 (35 percent), 5 (17 percent) and 1 (15 percent). The dominant groups in terms of numbers were the diving ducks (53 percent) and the loons, grebes and cormorants (38 percent) (Table B25).

Area 4N

This area, located on the north side of the Westshore causeway has been subject to siltation from the Fraser River (Appendix A; Appendix B, Section 2). This factor, coupled with its position near the shoreline has resulted in large expanses of shallow water, particularly at low tide. At high tide, water covered approximately 80 percent of the area yet most birds were observed 500 m or more from the causeway in Zones 8 (36 percent), 7 (33 percent) and 9 (25 percent) (Table B26).

The shallow water conditions were reflected in the species composition of the area. Shorebirds were most common (63 percent) and

TABLE 5 OBSERVATION POINT 3S

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group % Area Total Total
LOONS, GREBES, CORMORANTS	LOW & RISING	2(5)	-	-	-	11(26)	3(7)	27(63)	-	-	-	43(38)
	HIGH & FALLING	-	6(12)	-	6(12)	12(24)	8(18)	1(2)	8(18)	6(12)	3(6)	50(13)
GREAT BLUE HERON	LOW & RISING											- -
	HIGH & FALLING											- -
BRANT	LOW & RISING											- -
	HIGH & FALLING											- -
DABBLING DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
DIVING DUCKS	LOW & RISING	10(17)	7(12)	1(2)	7(12)	8(14)	13(22)	8(14)	5(8)	-	-	59(53)
	HIGH & FALLING	12(12)	10(10)	-	67(64)	-	3(3)	10(10)	2(2)	-	-	104(27)
UNIDENTIFIED DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
RAPTORS	LOW & RISING											- -
	HIGH & FALLING											- -
SHORE BIRDS	LOW & RISING											- -
	HIGH & FALLING											- -
GULLS AND TERNS	LOW & RISING	-	-	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	121(56)	3(1)	3(1)	15(7)	1(<1)	-	10(5)	62(29)	-	-	215(56)
ALCIDS	LOW & RISING	-	-	-	-	-	-	4(100)	-	-	-	4(4)
	HIGH & FALLING	-	-	-	-	-	-	2(40)	3(60)	-	-	5(1)
PASSERINES	LOW & RISING	5(100)	-	-	-	-	-	-	-	-	-	5(5)
	HIGH & FALLING	10(100)	-	-	-	-	-	-	-	-	-	10(3)
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	17(15)	7(6)	1(1)	7(6)	19(17)	16(14)	39(35)	5(5)	-	-	111
	HIGH & FALLING	143(37)	19(5)	3(1)	88(23)	13(3)	11(3)	23(6)	75(20)	6(2)	3(1)	384

TABLE 6 OBSERVATION POINT 4N

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group Total (% Area Total)
LOONS, GREBES, CORMORANTS	LOW & RISING	-	-	-	-	11(100)		-	-	-	-	11(2)
	HIGH & FALLING	2(1)	1(<1)	2(1)	5(2)	-		6(3)	2(1)	110(64)	43(25)	171(6)
GREAT BLUE HERON	LOW & RISING					6(50)	5(42)	1(8)				12(2)
	HIGH & FALLING			1(25)		-	3(75)	-				4(<1)
BRANT	LOW & RISING							6(9)	40(61)	20(30)		66(11)
	HIGH & FALLING							-	-	530(95)	40(7)	570(21)
DABBLING DUCKS	LOW & RISING							192(100)				192(33)
	HIGH & FALLING							-				-
DIVING DUCKS	LOW & RISING	-		-	-			53(43)	20(16)	20(16)	30(24)	123(21)
	HIGH & FALLING	3(2)		6(3)	2(1)		25(15)	74(44)	55(32)	-	5(3)	170(6)
UNIDENTIFIED DUCKS	LOW & RISING							30(100)				30(5)
	HIGH & FALLING							-				-
RAPTORS	LOW & RISING											
	HIGH & FALLING											
SHORE BIRDS	LOW & RISING							-	-		40(100)	40(7)
	HIGH & FALLING							800(47)	900(53)		-	1,700(63)
GULLS AND TERNS	LOW & RISING	-	-	-	-	19(18)		84(82)	-	-	-	103(18)
	HIGH & FALLING	9(15)	6(10)	9(15)	6(10)	-		3(5)	1(2)	24(39)	3(4)	61(2)
ALCIDS	LOW & RISING											
	HIGH & FALLING											
PASSERINES	LOW & RISING	-										-
	HIGH & FALLING	2(100)										2(<1)
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	-	-	-	-	36(6)	5(<1)	366(63)	60(10)	40(7)	70(12)	577
	HIGH & FALLING	16(<1)	7(<1)	18(<1)	13(<1)	-	28(1)	883(33)	958(36)	664(25)	91(3)	2,678

substantial numbers of brant were present (21 percent). At low tide, 60 percent of the area consisted of exposed mud flats and birds were confined to a few zones: 7 (63 percent), 10 (12 percent) and 8 (10 percent). The shallow water conditions attracted both dabbling (33 percent) and diving ducks (21 percent) as well as some gulls and terns (18 percent) (Table B26).

Area 4S

On the whole, more birds were present at high rather than low tide but if a correction factor for more high tide visits is included, more birds were observed at low tide. Low tide conditions exposed 50 percent of the area and most birds were located in three zones: 10 (47 percent), 7 (40 percent) and 3 (6 percent) (Table B27). Ducks, both unidentified (44 percent) and diving (8 percent) were most common but large numbers of shorebirds were present (35 percent). At high tide, water covered approximately 70 percent of the area yet birds again avoided the causeway, choosing Zones 9 (68 percent), 8 (18 percent) and 10 (7 percent) (Table B27). Almost all birds present were waterfowl: unidentified ducks (40 percent), brant geese (36 percent) and diving ducks (20 percent).

Area 5N

At high tide 50 percent of the area was exposed mud and sand and most birds were observed in Zones 8 (43 percent), 9 (27 percent) and 4 (12 percent) (Table B28). The shallow waters and exposed regions attracted shorebirds (91 percent), gulls and terns (4 percent) and brant (2 percent) (Table B28). At low tide, the area was all mud except for a few isolated ponds. Shorebirds were predominant (66 percent) but gulls and terns (27 percent) and brant (11 percent) were also present.

TABLE 7 OBSERVATION POINT 4S

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group % Area Total Total
LOONS, GREBES, CORMORANTS	LOW & RISING	-	-	-	-	-	-	-	-	-	-	-
	HIGH & FALLING	1(2)	-	-	-	-	-	3(8)	12(33)	6(17)	14(40)	36(<1)
GREAT BLUE HERON	LOW & RISING	-	-	-	-	2(10)	1(5)	17(85)	-	-	-	20(<1)
	HIGH & FALLING	-	-	-	-	-	-	2(67)	-	-	1(33)	3(<1)
BRANT	LOW & RISING	-	-	210(100)	-	-	-	-	-	-	-	210(6)
	HIGH & FALLING	-	-	-	-	-	210(12)	-	-	1,350(76)	210(12)	1,770(36)
DABBLING DUCKS	LOW & RISING	-	-	-	51(85)	3(3)	6(12)	-	-	-	-	60(2)
	HIGH & FALLING	-	12(11)	-	-	23(21)	-	-	-	-	72(68)	107(3)
DIVING DUCKS	LOW & RISING	-	-	2(<1)	-	21(8)	42(16)	-	-	100(38)	100(38)	265(8)
	HIGH & FALLING	3(<1)	2(<1)	10(1)	-	1(<1)	22(2)	5(<1)	878(90)	3(<1)	56(6)	980(20)
UNIDENTIFIED DUCKS	LOW & RISING	-	-	-	-	-	-	-	-	-	1,500(100)	1,500(44)
	HIGH & FALLING	-	-	-	-	-	-	-	-	2,000(100)	-	2,000(40)
RAPTORS	LOW & RISING											- -
	HIGH & FALLING											- -
SHORE BIRDS	LOW & RISING	-	-	-	-	-		1,200(100)	-	-	-	1,200(35)
	HIGH & FALLING	-	-	-	-	-		-	-	-	-	- -
GULLS AND TERNS	LOW & RISING	4(2)	-	-	21(12)	10(6)	-	140(80)	-	-	-	175(5)
	HIGH & FALLING	2(4)	8(17)	11(23)	-	17(36)	1(2)	-	8(17)	-	-	47(<1)
ALCIDS	LOW & RISING											- -
	HIGH & FALLING											- -
PASSERINES	LOW & RISING	-	-	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	5(100)	-	-	-	-	-	-	-	-	-	5(<1)
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	4(<1)	-	212(6)	72(2)	36(1)	49(1)	1,357(40)	-	100(3)	1,600(47)	3,430
	HIGH & FALLING	11(<1)	22(<1)	21(<1)	-	41(1)	233(5)	10(<1)	898(18)	3,359(68)	353(7)	4,948

TABLE 8 OBSERVATION POINT 5N

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group % Area Total Total
LOONS, GREBES, CORMORANTS	LOW & RISING									-	-	-
	HIGH & FALLING									6(60)	4(40)	10(<1)
GREAT BLUE HERON	LOW & RISING	-	-	-	-					-	-	-
	HIGH & FALLING	1(1)	9(7)	1(1)	3(2)					91(73)	19(15)	124(<1)
BRANT	LOW & RISING							-		-	10(100)	10(11)
	HIGH & FALLING							16(3)		345(67)	151(29)	512(2)
DABBLING DUCKS	LOW & RISING				-	-		-	-		-	-
	HIGH & FALLING				40(20)	39(19)		33(16)	2(1)		90(44)	204(<1)
DIVING DUCKS	LOW & RISING				-			-				-
	HIGH & FALLING				6(1)			35(5)		316(49)	290(45)	647(2)
UNIDENTIFIED DUCKS	LOW & RISING											
	HIGH & FALLING											
RAPTORS	LOW & RISING		-								-	
	HIGH & FALLING		1(50)								1(50)	2(<1)
SHORE BIRDS	LOW & RISING	4(7)		-	10(17)	-	-	15(25)	10(17)	10(17)	10(17)	59(66)
	HIGH & FALLING	-		2(<1)	3,200(13)	1,200(5)	1,108(4)	1,510(6)	11,990(48)	5,990(24)	15(<1)	25,025(91)
GULLS AND TERNS	LOW & RISING	4(16)					5(21)	15(63)				24(27)
	HIGH & FALLING				1(<1)		-	-		600(57)	450(43)	1,051(4)
ALCIDS	LOW & RISING											
	HIGH & FALLING											
PASSERINES	LOW & RISING											
	HIGH & FALLING											
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	1(1)	-	-	10(11)	-	-	30(34)	10(11)	10(11)	20(22)	89
	HIGH & FALLING	8(<1)	10(<1)	3(<1)	3,250(12)	1,239(4)	1,113(4)	1,584(6)	11,992(43)	7,348(27)	1,020(4)	27,575

Area 5S

Even at high tide, approximately 75 percent of this area consisted of exposed mud and sand. Birds were primarily found on or near the water in Zones 10 (51 percent), 7 (20 percent) and 9 (12 percent) (Table B29). Brant were most common (50 percent) but shorebirds (35 percent) and gulls and terns (13 percent) were observed as well. At low tide, little or no water was present in the area. Birds tended to be spread through several zones but were more evident away from the causeway in Zones 9 (37 percent), 8 (30 percent) and 5 (18 percent) (Table B29). Gulls and terns (89 percent) were most prevalent but several passerines (7 percent) and great blue herons (4 percent) were observed.

The habitat preferences of individual species are outlined below from literature reviews and field observations.

B6.3 LOONS, CORMORANTS AND GREBES

Two speciesof cormorants, the double-crested (*Phalacrocorax auritus*) and the pelagic (*P. pelagicus*), are commonly observed on the delta, but the double-crested is most numerous. Taylor (1974) reported that the double-crested cormorants gather in numbers during April when they feed on runs of oolichans.

Grebes are also common in the area. The western grebe (*Aechmophorous occidentalis*) is a year round inhabitant except for the nesting season in July and August (Taylor, 1974).

Little or no site-specific information is available from literature for this group of birds. During the 1977 field survey, this group comprised 5 percent of the total low tide and 3 percent of the

TABLE 9 OBSERVATION POINT 5S

ZONE (ZONE VALUES AND PERCENT OF GROUP TOTAL)

SPECIES	TIDE	1	2	3	4	5	6	7	8	9	10	Group Total % Area Total
LOONS, GREBES, CORMORANTS	LOW & RISING											- -
	HIGH & FALLING											- -
GREAT BLUE HERON	LOW & RISING	1(100)	-	-	-	-	-	-	-	-	-	1(4)
	HIGH & FALLING	-	4(25)	-	1(6)	-	-	-	1(6)	9(56)	1(6)	16(1)
BRANT	LOW & RISING	-	-	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	-	-	-	-	-	-	-	-	-	700(100)	700(50)
DABBLING DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
DIVING DUCKS	LOW & RISING	-	-	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	-	-	2(100)	-	-	-	-	-	-	-	2(<1)
UNIDENTIFIED DUCKS	LOW & RISING											- -
	HIGH & FALLING											- -
RAPTORS	LOW & RISING											- -
	HIGH & FALLING											- -
SHORE BIRDS	LOW & RISING	-	-	-	-	-	-	-	-	-	-	- -
	HIGH & FALLING	70(14)	1(<1)	18(4)	100(20)	-	10(2)	200(40)	-	100(20)	-	499(35)
GULLS AND TERNS	LOW & RISING	2(8)	-	-	-	1(4)	-	4(17)	-	10(42)	8(33)	25(93)
	HIGH & FALLING	1(1)	2(<1)	1(1)	-	7(4)	5(3)	88(47)	2(1)	58(31)	24(13)	188(13)
ALCIDS	LOW & RISING											- -
	HIGH & FALLING											- -
PASSERINES	LOW & RISING	2(100)	-	-	-	-	-	-	-	-	-	2(7)
	HIGH & FALLING	2(67)	1(33)	-	-	-	-	-	-	-	-	3(<1)
ZONE TOTAL AND % AREA TOTAL	LOW & RISING	5(18)	-	-	-	1(4)	-	4(15)	-	10(37)	8(30)	27
	HIGH & FALLING	73(5)	9(4)	21(1)	101(7)	7(<1)	15(1)	288(20)	3(<1)	167(12)	725(51)	1,409

total high tide bird population (Table B21). A fish-eating group, they frequented areas with deeper water: 1 (65 percent), 3S (17 percent) and 2 (12 percent) at low tide and 1 (47 percent), 3N (21 percent) and 4N (17 percent) at high tide. In almost all situations, regardless of tide, they avoided the causeway or other dock structures, preferring Zones 7 to 10.

B6.4 GREAT BLUE HERONS

A significant portion of the lower mainland great blue heron (*Ardea herodius*) population (several hundred) may feed in the Westshore Terminal area. Swan Wooster (1967) reported an average annual population of 100 birds between Canoe Pass and the Tsawwassen Terminal. Pageot (1976) recorded a peak population (65) in the same area during September and November. They use the entire foreshore near the Westshore Terminal but Entech (1974) observed them most frequently in stands of bullrush and sedge. They often feed in eelgrass beds (Moody, pers. comm.) or move in with the tide, foraging for a variety of prey which includes frogs, Pacific sandcrab (*Cithariathys sordidus*) and starry flounder (*Platichthys stellatus*) (Paine, 1972; Hoos and Packman, 1974).

Herons are colonial nesters and while no colonies are located at the Westshore Terminal site, Entech (1974) reported the presence of a colony at Tsawwassen. This species is of considerable interest to the public, in part due to its high profile from a nesting colony in Stanley Park.

Although this species was not well represented during the 1977 field study at high tide (<1 percent), it is of considerable local interest as an aesthetic resource. As they are wading birds, water depths confined them to Areas 4S (61 percent), 4N (36 percent) and 5S

(3 percent) at low tide and Areas 5N (84 percent), 5S (11 percent) and 4N (3 percent) at high tide. Zones 5, 6 and 7 attracted most birds at low tide for unknown reasons. At high tide, the herons were distributed more widely within 3 areas. In 5N, 73 percent were located in Zone 9, 15 percent in 10 and 7 percent in 2. In 5S, Zone 9 had 56 percent of the herons while Zone 2 had 25 percent. Area 4N had 75 percent of its herons in Zone 6 and the balance in Zone 3.

B6.5 SWANS

Flocks of whistling (*Olor columbianus*) and trumpeter (*O. buccinator*) swans migrate through the Fraser River delta and small numbera have been observed in the Roberts Bank area (Hoos and Packman, 1974; Canadian Wildlife Service (CWS), unpublished data, 1976). Pageot (1976) observed three swans of undetermined identity during November in the area between the Westshore Terminal and Brunswick point (Brunswick Bay).

Until recently, the trumpeter swan faced extinction in North America, largely because of human pressure. It has made a strong recovery and areas such as Vancouver Island now support wintering populations of over 1,000 birds (Morris, 1969; Smith and Blood, 1972). Despite this recent recovery, the species should still be considered vulnerable.

B6.6 GEESE

Canada geese (*Branta canadensis*) are common in the general Fraser River area (Noble, 1972), but black brant (*Branta bernicla*) and lesser snow geese (*Chen caerulescens*) are more numerous in the specific Roberts Bank area. Swan Wooster (1967) reported an average annual population of 4,500 brant and snow geese between Brunswick point and the Tsawwassen Terminal.

Brant use the Fraser River delta coastline extensively on their northward migration (early March) as well as for a wintering area (Einarsen, 1965). Russell and Paish (1968) indicate that brant frequently feed and nest in the intercauseway area. Brant feed almost exclusively on eelgrass (*Zostera marina*). Its importance as a food item has been noted by several authors (Cottam and Munro, 1954; Einarsen, 1965; and Morrison, 1967) (see Section B3 above for eelgrass distribution).

Although large numbers (30,000 to 40,000) of snow geese migrate through the Fraser River delta, substantial numbers (7,000 to 15,000) also winter there (Russell and Paish, 1968; Halladay and Harris, 1972; Entech, 1974; Hoos and Packman, 1974; Ward and Gunn, 1973). The population of wintering geese starts to build up in October, reaching peak numbers by late November (Entech, 1974; Hoos and Packman, 1974). Russell and Paish (1968) and Burton (pers. comm.) have observed large concentrations of snow geese in Brunswick Bay in December and January. Pageot (1976) observed 1,000 snow geese in Brunswick Bay and about 45 in Tsawwassen Bay in mid-October.

Although they comprised only 6 percent of the total bird population at low and 9 percent at high tide, black brant are important visitors to the area. Brant generally feed on eelgrass in shallow water. Not unexpectedly, most geese therefore were observed in the shallows of Areas 4S (61 percent) and 4N (36 percent) at low and 4S (50 percent) and 5S (20 percent) at high tide (Table B21). In almost every instance, the birds avoided regions close to the causeway, preferring Zones 7 to 10.

B6.7 DUCKS

Over 200,000 ducks, both dabblers and divers, use the Fraser River delta between fall and spring (Halladay et al, 1970; CWS, 1976).

Taylor (1974) observed peak numbers of ducks (9,000 to 10,000) between Brunswick point and Tsawwassen Terminal during November and December.

Dabbling ducks are common along the foreshores but generally frequent inland waters or the freshwater marshes of the Fraser River. In the Roberts Bank area, C.W.S. (unpublished data, 1976) reported approximately 5,500 dabbling ducks in early March. Swan Wooster (1967) reported an average annual population of approximately 8,000 dabbling ducks on Roberts Bank and 4,000 between Brunswick Point and Tsawwassen Terminal. Pageot (1976) reported that the average fall population in Brunswick Bay was around 4,000 birds, of which the majority were American widgeon (*Anas americana*) and green-winged teal (*Anas carolinensis*). In Tsawwassen Bay, American widgeon and green-winged teal were also predominant with a steady increase in numbers until mid-October when the total population peaked at about 3,600 birds.

Although the delta foreshore areas are generally used as loafing sites, feeding does occur there. Harris (1966) noted that siltation along the Tsawwassen Terminal had created attractive feeding habitat for American widgeon and green-winged teal. Pageot (1976) noted a similar phenomenon at Westshore Terminal. The importance of the foreshore as feeding sites is dependent on various factors such as tidal conditions, food availability inland, and hunting pressure. Burgess (1970) and Hoos and Packman (1974) reported that the peak period of foreshore use was from September to November. Feeding habits of the various dabbling duck species varies, both with feeding sites and time of year.

Most diving ducks are concentrated in Boundary Bay. Greater scaup (*Aythya marila*), three species of scoter, surf (*Melanitta perspicillata*), white-winged (*M. deglandi*) and black (*M. nigrs*) and Barrow's goldeneye (*Bucephala islandica*) are the most common diving ducks on the

delta. Leach (1972) estimated a wintering population of approximately 15,000 for the delta itself but numbers for Roberts Bank are lacking. Pageot (1976) observed peak numbers of divers (approximately 230) at Brunswick Bay and approximately 400 in Tsawwassen Bay in mid-October.

Diving ducks generally feed in open water at depths up to 14.6 m (Noble, 1972). Except for the mergansers (fish eaters), most are omnivorous. Some of their food items include: blue mussels (*Mytilus edulia*), snails (*Cerithium* spp.), pondweeds (*Potamogeton* spp.) bullrush seeds (*Scirpus* spp.), sedge (*Carex lyngbei*) and smartweed (*Polygonum* spp.) (Noble, 1972).

B6.7.1 Dabbling Ducks Distribution

The study area did not support a large population of dabbling ducks during the period of this study. As Table B21 indicates, dabbling ducks represented 5 percent of the total bird population at low and 1 percent at high tide. These birds showed a preference for the shallow water Areas 4N (76 percent) and 4S (24 percent) at low tide and 5N (66 percent) and 4S (34 percent) at high tide (Table B21). Overall, dabbling ducks also preferred the north side of the causeway, perhaps because of lower slainity, greater feeding opportunities or a combination of factors. At low tide, they frequented Zone 7 of Area 4N (100 percent) and Zones 4 (85 percent) and 6 (12 percent) of Area 4S. Under high tide conditions, these ducks were most abundant in Zones 9 (76 percent) and 10 (12 percent) of Area 5N and Zones 10 (68 percent) and 5 (21 percent) of Area 4S.

B6.7.2 Diving Ducks Distribution

Diving ducks were more numerous than dabblers, representing 12 percent of the total population at low and 6 percent at high tide

(Table B21). Although observed in all areas, they preferred Areas 4S (47 percent), 4N (22 percent) and 3S (10 percent) at low tide. With high tide conditions, they moved closer to the main shorelines into Areas 4S (46 percent), 5N (30 percent) and 3N (9 percent). Like most birds, they avoided zones adjacent to the causeway, preferring Zones 5 to 10 during low tide. At high tide they restricted their activities even more and were seldom observed outside Zones 8, 9 or 10.

B6.7.3 Unidentified Ducks Distribution

Distance and haze prevented identification of some duck species. In all probability most unidentified ducks were diving ducks, particularly scaup. At low tide, this group made up a substantial portion (33 percent) of the total population while its presence was not so obvious at high tide (5 percent) (Table B21). Unidentified ducks were observed almost exclusively in Area 4S at both low (98 percent) and high tide (100 percent). The very fact that they were too distant to identify indicates that they were found in Zones 9 and 10.

B6.8 RAPTORS

Campbell et al (1972) have reported 22 raptorial species in the delta area. Hughes (1966) noted seven owl species, ten hawk species and one eagle in the same area. Marsh hawks (*Circus cyaneus*), red-tailed hawks (*Buteo jamaicensis*) and rough-legged hawks (*Buteo lagopus*) are the most common raptors on Roberts Bank. Pageot (1976) reported a maximum of one to three during fall observations in the Westshore Terminal area.

During the 1977 field study, raptors were seen infrequently (three occasions) and then only flying high over the study area. All three individuals were observed at high tide, flying over the exposed mudflats of Areas 5N and 5S (Table B21).

B6.9 SHOREBIRDS

Halladay and Harris (1972) estimated that approximately five million shorebirds were present during peak migration and one million overwintered on the delta. Hughes (1966) and CWS (1976) recorded 24 different species at various times of the year. Of these, the dunlin (*Calidris alpina*), the western sandpiper (*C. mauri*) and the least sandpiper (*C. minutilla*) are the most common between September and April (Hoos and Packman, 1974).

Information on population numbers in the Roberts Bank area is lacking, but Swan Wooster (1967) estimated an average annual population of 5,000 shorebirds between Brunswick Point and the Tsawwassen Terminal. Pageot (1976) reported peak fall population numbers (3,550) in November at Brunswick Bay and 1,000 in Tsawwassen Bay.

Food habits studies are lacking but Hoos and Packman (1974) suggested that Roberts Bank provides substantial food supplies in the form of polychaete worms, burrowing shrimp (*Callianessa californiensis*) and snails (*Cerithium* spp.).

During the study, they comprised 28 percent of the total population at low tide and 71 percent at high tide. Most birds were observed feeding in the shallow waters of Areas 4 and 5. At low tide, Areas 4S (92 percent), 5N (5 percent) and 4N (3 percent) contained all shorebirds while at high tide all were located in 5N (92 percent), 4N (6 percent) and 5S (2 percent). The change from a north location at high tide to a south location at high tide could be related to food availability.

B6.10 GULLS AND TERNS

The Fraser estuary and delta area maintains a peak gull population of approximately 70,000 birds (CWS, 1976). Of the eight species present, the glaucous-winged (*Carus glaucscens*) is most numerous (40,000) (Hoos and Packman, 1974). Drent et al (1971) recorded the locations of major roosting sites, the closest to Westshore Terminal being located off Westham Island. Pageot (1976) recorded peak populations of 1,700 in Brunswick Bay and 550 in Tsawwassen Bay.

An opportunistic group of birds, they feed on an assortment of waste products provided at disposal areas.

During the 1977 field study, gulls and terns represented 9 percent of the low tide and 5 percent of the high tide population. An adaptable and opportunistic group of birds, they were observed in almost all areas although they frequented Areas 4S (43 percent), 4N (25 percent) and 1 (11 percent) for the most part during low tide conditions. At high tide, most were on the mudflats of Areas 5N (53 percent) and 5S (10 percent) but others frequented 3S (11 percent).

B6.11 ALCIDS

Alcids, not common in the study area, constituted less than 1 percent of the total high or low tide populations in the 1977 study (Table B21). Typically an offshore, marine group, they were observed in Areas 3S (40 percent), 2 (40 percent) and 1 (20 percent) during low tide. Their position did not vary much at high tide: Area 2 (52 percent), 1 (27 percent) and 3N (15 percent). At low tide, they preferred Zone 7 (100 percent) of Area 3S and Zone 7 (75 percent) of Area 2. At high tide, they showed no obvious zonal preference: in Area 2, 20 percent were observed in Zone 2 and 13 percent in each of Zones 1, 3 and 4. In Area 3N, 54 percent preferred Zone 7.

B6.12 PASSERINES

Sverre (1974) and CWS (1976) reported 67 species of passerines on the Fraser delta. Pageot (1976) noted eight species in Brunswick Bay and a peak fall population of 550 birds in late October. At Tsawwassen Bay, ten species were recorded but only 200 birds for a given observation period.

Passerines were rarely recorded during the field study, but comprised less than 1 percent of the total populations. They mostly were observed in flight over the various areas. In every instance, the birds were in close proximity to the causeway (Zone 1).

B6.13 AVIFAUNA SUMMARY

During the 1977 field survey, more birds were observed at high tide situations than at low tide even if the bias due to extra number of high tide visits was accommodated (Table B21). At high tide, most birds were observed in Areas 5N (72 percent), 4S (13 percent) and 4N (7 percent) (Table B21). Under these conditions, the greatest percentage of birds were shorebirds (71 percent), brant (9 percent) and diving ducks (6 percent).

Birds were observed at slightly different locations at low tide, most in Areas 4S (74 percent), 4N (12 percent) and 1 (6 percent) (Table B21). Of these birds, the majority were unidentified ducks (33 percent), shorebirds (28 percent) and diving ducks (12 percent). Species observed during the course of the study are listed in Annex 4.

Almost every bird group avoided zones adjacent to the Westshore Terminal pod. A minimum of 78 percent of all birds per area were

consistently observed at least 100 m from the causeway (Zones 4-10). Furthermore, with the exception of Area 3S (40 percent), a minimum of 68 percent of all birds in each area were located at least 500 m from the causeway (Zones 7-10).

Numerous broad overviews of the Fraser River delta have emphasized the importance of this region to waterfowl and birds in general (Swan Wooster, 1967; Entech, 1974; Hoos and Packman, 1974; Taylor, 1974). Unfortunately little information is available concerning avifaunal use of Southern Roberts Bank. As a result it is difficult to assess what proportion of the Fraser River delta population utilizes the area. The fact that each area of the delta is an integral part of the complex ecosystem makes it even more difficult to assess the wildlife value of a particular area.

Despite these difficulties, if one attempts to quantify the "wildlife value" of discrete areas, certain generalizations can be made. Using a system of evaluating foreshore areas on their marsh area and bird use, Sverre (1974) suggested that a wildlife habitat value could be calculated for a particular area. Based on this system, Taylor (1974) concluded that Westham Island and Boundary - Mud Bay regions had the highest values (29.5 and 26.5) while the Iona - Sea Islands had the lowest (10.0). The region including Westshore Terminal facility (Brunswick) had a value only slightly higher (10.5) than the Iona- Sea Islands region.

These rough estimations would appear to agree fairly closely with the conclusions of Swan Wooster (1967) which suggested that the Brunswick to Tsawwassen area was of low to intermediate importance in terms of wildlife conservation potential. Various unpublished surveys of the region also support these conclusions.

Nonetheless, one must be careful in interpreting these observations. While the Westshore Terminal area is less important in comparative terms, it nonetheless supports a substantial number of birds. Furthermore, the area also appears to provide attractive habitat to several key species such as great blue herons and brant which may be sensitive to development activities.

B7.0 AMPHIBIANS, REPTILES AND MAMMALS

The discussion of mammals in the vicinity of Roberts Bank is limited to those species excluding domestics which have been considered in the land use presentation.

B7.1 AMPHIBIANS AND REPTILES

Several amphibian and reptile species inhabiting the Fraser River delta have been reported (Carl, 1944, 1966; Hoos and Packman, 1974; Northcote, 1974). The amphibians include: Northwestern toad (*Bufo boreas boreas*), Pacific tree toad (*Hyla regilla*), Red-legged frog (*Rana aurora aurora*), Western spotted frog (*R. pretoisa pretoisa*), Bullfrog (*R. catesbiana*), Green frog (*R. clamitans*), Pacific Coast newt (*Taricha granulosa granulosa*), Long-toed salamander (*Ambystoma macrodactylum*), British Columbia salamander (*A. gracile decorticatum*), Pacific giant salamander (*Dicamptodon ensatus*), Western red-backed salamander (*Plethodon vehiculum*) and Red salamander (*Ensatina eschscholtzi*). Reptile species include: Northwestern garter snake (*Thamnophis sirtalis*), Puget garter snake (*T. ordinoides*), Wandering garter snake (*T. elegans ragrams*), Pacific terrapin (*Clemys marmorata*) and Western painted turtle (*Chrysemys picta belli*).

Hoos and Packman (1974) indicated that the amphibians and reptiles present primarily inhabit freshwater systems. Consequently, it is doubtful that significant numbers of any of these species regularly frequent areas in the immediate vicinity of the proposed development.

B7.2 MAMMALS

Aquatic mammals reported as resident and having breeding populations near the lower Fraser River include: Bendire shrew (*Sorex*

bendiri bendiri), Wandering shrew (*S. vagrens vagrens*), Beaver (*Castor canadensis leucondontas*), Muskrat (*Ondatra zibethica osoyoosensis*), Racoon (*Procyon cotor*), Mink (*Mustella vison energumenos*) and Canadian river otter (*Lutra canadensis pacifica*) (Cowan and Guiget, 1965; Northcote, 1974). These mammals are apart from those such as bats, rats and nutria which are not as heavily dependent on the river for habitat or food. These mammals are primarily associated with the sloughs, marshes and river bank and are not generally found in the open marine environs. As such, it is unlikely that any of the above would be regularly found in proximity to the existing facilities.

Marine mammals are the only other species frequenting the proximity of Roberts Bank. These include the Harbour (or hair) seal (*Phoca vitulina*), Harbour porpoise (*Phocoena phocoena*) and Killer whale (*Orcinus orca*) (Dr. Bigg, pers. comm.).

A colony of approximately 200 harbour seals are resident near the mouth of the Fraser River (Dr. Bigg, pers. comm.). From this location they may disperse throughout the Strait of Georgia in summer and frequent the vicinity of the Roberts Bank development. Over winter periods, harbour seal remain relatively sedentary with regard to habitat and very seldom frequent areas removed from coastal sanctuaries. Most movement and migration occurs during spring and summer months (Banfield, 1974). Sitings of harbour seal near Roberts Bank have been primarily during the spring and summer periods when weather conditions were more conductive to visual observations (Dr. Bigg, pers. comm.). However, it is highly probable that year-round activity occurs in the area.

It is estimated that 2 to 3 dozen harbour porpoise frequent the Strait of Georgia and the vicinity of Roberts Bank. Harbour porpoise

are less gregarious than other species of porpoise and normally travel in groups of up to a dozen.

Killer whales frequent the Strait of Georgia year-round but are sighted more frequently in the summer. Approximately 70 individuals appear on a regular basis with approximately 60 occurring sporatically throughout the Strait (Dr. Bigg, pers. comm.). Other species of marine mammals have been recorded in the Strait and near the Fraser mouth. These are rare or uncommon transients. Such species include the Northern fur seal (*Callorhinus ursinus cynocephalus*), Northern sea lion (*Eumetopias jubata*), Right whale (*Balaena glacialis*), Blue whale (*Balaenoptera musculus*), Dall's porpoise (*Phoconoides dalli*) and the Pilot whale (*Glovicephala macrorhyncha*) (Cowan and Guiget, 1965; Banfield, 1974; Northcote, 1974).

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ANNEX B-1

INTERTIDAL BENTHIC RESULTS

TABLE B-1-1

STATION: A-1[1]

ORGANISM	#[2]
ANNELIDA	
POLYCHAETA	
Capitella capitata	166
Eteone longa	26
Abarenicola pacifica	14
Spionidae	6
Manayunkia aestuarina	6
Paraonides platybranchia	2
ARTHROPODA	
AMPHIPODA	
Corophium salmonis	14
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	10
TOTAL NUMBER OF ORGANISMS	244
TOTAL NUMBER OF TAXA	8
WEIGHT WEIGHT (g)	0.14

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-2:

STATION: A-2

ORGANISM	#
ANNELIDA	
POLYCHAETA	
Paraonides platybranchia	28
Capitella capitata	25
Spionidae	7
Scoloplos armiger	10
Eteone longa	6
ARTHROPODA	
AMPHIPODA	
Eohaustorius washingtonianus	36
Paraphoxus sp. (*Trichophoxus*? sp.)	1
Corophium salmonis	1
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	110
Mya arenaria	1
Protothaca sp.	1
TOTAL NUMBER OF ORGANISMS	226
TOTAL NUMBER OF TAXA	11
WEIGHT WEIGHT (g)	0.37

Sample Residue: sand

TABLE B-1-3:

STATION: A-3[1]

ORGANISM	#[2]
ASCHELMINTHES	
NEMATODA	2
ANNELIDA	
POLYCHAETA	
Paraonides platybranchia	26
Eteone longa	18
Scoloplos armiger	4
Capitella capitata	2
ARTHROPODA	
COPEPODA	
Harpaticoida copepods	8
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	568
Mya arenaria	2
TOTAL NUMBER OF ORGANISMS	630
TOTAL NUMBER OF TAXA	8
WET WEIGHT (g)	0.76

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-4:

STATION: A-4

ORGANISM	#
ANNELIDA	
POLYCHAETA	
Paraonides platybranchia	3
Eteone longa	1
ARTHROPODA	
AMPHIPODA	
Paraphoxus sp. (*Trichophoxus*? sp.)	7
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	188
Mya arenaria	2
TOTAL NUMBER OF ORGANISMS	201
TOTAL NUMBER OR TAXA	5
WET WEIGHT (g)	0.26

Sample Residue: sand

TABLE B-1-5:

STATION: A-5

ORGANISM	#
NEMERTEA	3
ANNELIDA	
POLYCHAETA	
Capitella capitata	1
Scoloplos armiger	1
ARTHROPODA	
AMPHIPODA	
Paraphoxus sp. (*Trichophoxus*? sp.)	6
Corophium salmonis	1
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	145
TOTAL NUMBER OF ORGANISMS	157
TOTAL NUMBER OF TAXA	6
WET WEIGHT (g)	0.15

Sample Residue: sand

TABLE B-1-6:

STATION: B-1[1]

ORGANISM	#[2]
ANNELIDA	
OLIGOCHAETA	4
POLYCHAETA	
Capitella capitata	400
Spionidae	26
Eteone longa	8
Paraonides platybranchia	8
MOLLUSCA	
GASTROPODA	
Batillaria sp.	6
BIVALVIA	
Macoma inconspicua	4
TOTAL NUMBER OF ORGANSIMS	456
TOTAL NUMBER OF TAXA	7
WET WEIGHT (g)	0.62

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-7:

STATION: B-2[1]

ORGANISM	#[2]
ASCHELMINTHES	
NEMATODA	4
ANNELIDA	
OLIGOCHAETA	4
POLYCHAETA	
Paraonides platybranchia	132
Capitella capitata	70
Spionidae	38
Scoloplos armiger	34
Eteone longa	26
ARTHROPODA	
COPEPODA	
Harpacticoida copepods	2
CUMACEA	
Lamprops sp.	2
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	42
TOTAL NUMBER OF ORGANISMS	354
TOTAL NUMBER OF TAXA	10

TABLE B-1-7 Cont'd:

STATION: B-2[1]

ORGANISM	#[2]
WET WEIGHT (g)	0.48

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-8:

STATION: B-3

ORGANISM	#
NEMERTEA	1
ANNELIDA	
POLYCHAETA	
Capitella capitata	16
Scolôplos armiger	12
Eteone longa	11
Paraonides platybranchia	5
Spionidae	4
Glycinde picta	2
Nereis sp.	1
ARTHROPODA	
COPEPODA	
Harpacticoida copepods	1
CUMACEA	
Lamprops sp.	1
AMPHIPODA	
Eohaustorius washingtonianus	32
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	126

TABLE B-1-8 Cont'd:

STATION: B-3

ORGANISM	#
TOTAL NUMBER OF ORGANISMS	212
TOTAL NUMBER OF TAXA	12
WET WEIGHT (g)	0.36

Sample Residue: sand

TABLE B-1-9:

STATION: B-4

ORGANISM	#
ANNELIDA	
POLYCHAETA	
Scoloplos armiger	14
Eteone longa	6
Spionidae	6
Paraonides platybranchia	2
ARTHROPODA	
AMPHIPODA	
Eohaustorius washingtonianus	41
Paraphoxus sp. (*Trichophoxus*? sp.)	9
Anisogammarus confervicolus	1
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	193
Mya arenaria	2
TOTAL NUMBER OF ORGANISMS	274
TOTAL NUMBER OF TAXA	9
WET WEIGHT (g)	0.35

Sample Residue: sand

TABLE B-1-10:

STATION: B-5

ORGANISM	#
ASCHELMINTHES	
NEMATODA	4
ANNELIDA	
POLYCHAETA	
Scoloplos armiger	205
Glycinde picta	4
Paraonides platybranchia	2
Eteone longa	1
Spionidae	1
ARTHROPODA	
CUMACEA	
Lamprops sp.	4
AMPHIPODA	
Eohaustorius washingtonianus	18
Paraphoxus sp. (*Trichophoxus*? sp.)	12
Corophium salmonis	1
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	88
Mya arenaria	1

TABLE B-1-10 Cont'd:

STATION: B-5

ORGANISM	#
TOTAL NUMBER OF ORGANISMS	341
TOTAL NUMBER OF TAXA	12
WET WEIGHT (g)	0.52

Sample Residue: sand

TABLE B-1-11:

STATION: C-1[1]

ORGANISM	#[2]
ANNELIDA	
POLYCHAETA	
Spionidae	108
Capitella capitata	52
Eteone longa	28
Amphicteis sp.	20
Glycinde picta	2
ARTHROPODA	
CUMACEA	
Lamprops sp.	2
AMPHIPODA	
Corophium salmonis	
MOLLUSCA	
GASTROPODA	
Batillaria sp.	4
BIVALVIA	
Macoma inconspicua	6
Mya arenaria	2
TOTAL NUMBER OF ORGANISMS	240
TOTAL NUMBER OF TAXA	9
WET WEIGHT (g)	0.64

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-12:

STATION: C-2[1]

ORGANISM	#[2]
ASCHELMINTHES	
NEMATODA	4
ANNELIDA	
POLYCHAETA	
Spionidae	222
Capitella capitata	74
Eteone longa	18
Scoloplos armiger	10
Glycinde picta	2
ARTHROPODA	
CUMACEA	
Lamprops sp.	2
AMPHIPODA	
Corophium salmonis	2
MOLLUSCA	
GASTROPODA	
Batillaria sp.	4
Acteocina sp.	2
BIVALVIA	
Macoma inconspicua	16

TABLE B-1-12:

STATION: C-2[1]

ORGANISM	#[2]
TOTAL NUMBER OF ORGANISMS	356
TOTAL NUMBER OF TAXA	11
WET WEIGHT (g)	0.52

Sample Residue: sand

[1] 1/2 the sample sorted
[2] 1/2 the sample extrapolated to a whole

TABLE B-1-13:

STATION: C-3

ORGANISM	#
ANNELIDA	
POLYCHAETA	
Spionidae	133
Eteone longa	6
Scoloplos armiger	2
Armandia brevis	2
Nephtys cornuta franciscana	1
ARTHROPODA	
CUMACEA	
Lamprops sp.	5
TANAIDACEA	
Leptochelia dubia	1
MOLLUSCA	
BIVALVIA	
Macoma inconspicua	84
Lyonsia sp.	1
Mya arenaria	1
TOTAL NUMBER OF ORGANISMS	236
TOTAL NUMBER OF TAXA	10
WET WEIGHT (g)	0.21

Sample Residue: sand

ANNEX B-2

SUBTIDAL BENTHIC RESULTS

TABLE B-2-1:

STATION: A 6

ORGANISM	Sample No. 1	2	3
ANNELIDA			
POLYCHAETA			
Scoloplos armiger	26	24	12
Ampharete sp.	9	14	27
Polydora ligni	3	-	-
Glycinde picta	2	-	-
Eteone longa	2	-	-
Spionidae	-	17	-
Paraonides platybranchia	-	3	-
Nephtys sp.	-	1	-
Pseudopolydora kempi japonica	-	-	4
ARTHROPODA			
CIRRIPEDIA			
Balanus sp.	2	-	36
MYSIDACEA			
juveniles	-	1	1
CUMACEA			
Lamprops sp.	61	67	158
Cumella vulgaris	-	7	24
ISOPODA			
Synidotea nebulosa	-	-	1
Pentidotea resecta	5	-	7
AMPHIPODA			
Atylus sp.	53	9	53
Anisogammarus confervicolus	-	-	28

TABLE: B-2-1 Cont'd:

STATION: A 6

ORGANISM	Sample No. 1	2	3
AMPHIPODA Cont'd.			
Corophium sp.	-	4	1
Eohaustorius washingtonianus	-	1	-
Aoridae amphipods	-	-	7
DECAPODA			
zoea	1	-	-
MOLLUSCA			
GASTROPODA			
larvae	-	-	3
BIVALVIA			
Macoma sp.	-	2	-
Macoma juveniles	114	176	129
Mytilus edulis	2	-	15
Kellia suborbicularis	1	-	2
Mya arenaria	-	-	1
ECHINODERMATA			
OPHIUROIDEA			
juveniles	-	-	1
CHAETOGNATHA			
Sagitta elegans	4	-	-
TOTAL NUMBER OF ORGANISMS	285	326	510

TABLE B-2-1 Cont'd:

STATION: A 6

ORGANISM	Sample No. 1	2	3
TOTAL NUMBER OF TAXA	14	12	18
WET WEIGHT (g)	0.65	0.39	1.19

Sample Residue: Sample 1 - sand, empty polychaete tubes
2 - sand, shell pieces, empty polychaete tubes
3 - sand, eelgrass, empty polychaete tubes

TABLE B-2-2:

STATION: A 7

ORGANISM	Sample No. 1	2	3
NEMERTEA	-	1	-
ANNELIDA			
POLYCHAETA			
Hesionidae	6	-	-
Polydora ligni	4	1	-
Scoloplos armiger	2	1	1
Nephtys cornuta franciscana	1	3	-
Ampharete sp.	-	2	2
Glycinde picta	-	1	1
Prionospio malmgreni	-	1	-
Paraonides platybranchia	-	1	-
Spionidae immature	-	-	1
ARTHROPODA			
CUMACEA			
Lamprops sp.	9	16	9
Oxyurostylis sp.	-	1	-
TANAIDACEA			
Leptochelia dubia	1	-	1
ISOPODA			
Synidotea nebulosa	-	2	-
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	15	1	-
Lysianassidae amphipods	3	1	-
Oedicerotidae amphipods	1	2	-

TABLE B-2-2 Cont'd:

STATION: A 7

ORGANISM	Sample No. 1	2	3
AMPHIPODA Cont'd.			
Anisogammarus confervicolus	1	1	3
Photis sp.	-	21	1
Atylus sp.	-	11	2
Isaeidae amphipods	-	7	-
DECAPODA			
Crangon sp.	-	-	1
zoea	1	-	-
mysis	1	-	-
MOLLUSCA			
GASTROPODA			
Gastropteron sp.	-	-	1
BIVALVIA			
Macoma sp.	-	2	-
Macoma juveniles	379	-	4
Kellia suborbicularis	13	15	6
Axinopsis serricata	-	5	-
Mya arenaria	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
damaged specimens	-	5	1
juveniles	4	-	-
TOTAL NUMBER OF ORGANISMS	441	102	34

TABLE B-2-2 Cont'd:

STATION: A 7

ORGANISM	Sample No. 1	2	3
TOTAL NUMBER OF TAXA	15	23	14
WET WEIGHT (g)	0.28	0.26	0.38

Sample Residue: Sample 1 - sand, broken shell
2 - sand, broken shell, fine plant debris
3 - sand, broken shell

TABLE B-2-3:

STATION: A 8

ORGANISM	Sample No. 1	2	3
NEMERTEA	1	5	1
ANNELIDA			
POLYCHAETA			
Lumbrineris latreilli	24	25	19
Nephtys cornuta franciscana	21	24	26
Scoloplos armiger	8	4	13
Maldanidae	8	16	5
Prionospio malmgreni	7	3	7
Ampharete sp.	4	3	11
Glycinde picta	4	8	6
Pseudopolydora dempi japonica	3	7	-
Peisidice aspera	3	4	3
Armandia brevis	2	-	5
Magelona sp.	2	4	3
Tharyx sp.	2	2	-
Eteone longa	1	1	2
Polydora ligni	1	1	-
Prionospio pinnata	1	-	1
Pectinaria sp.	1	1	-
Nephtys sp.	1	2	2
Ohuphis sp.	1	-	3
Nereis sp.	-	1	-
Hesionidae	-	2	-
Syllidae	-	1	-
Spiophanes bombyx	-	1	1
Laonice cirrata	-	2	-
Glycera sp.	-	1	1
Capitellidae	-	-	5
Sabellidae	-	-	2
Spionidae juveniles	-	-	7

TABLE B-2-3 Cont'd:

STATION: A8

ORGANISM	Sample No. 1	2	3
SIPUNCULIDA			
Dendrostoma sp.	1	-	-
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	-	2	-
CUMACEA			
Lamprops sp.	63	44	55
Oxyurostylis sp.	-	-	1
Cumella vulgaris	-	-	1
AMPHIPODA			
Caprella sp.	5	14	8
Paraphoxus sp. (*Trichophoxus*? sp.)	4	5	3
Atylus sp.	4	-	4
Ampithoe sp.	9	-	-
Anisogammarus confervicolus	7	-	-
Photis sp.	26	8	45
Lysianassidae amphipods	1	-	3
Oedicerotidae amphipods	1	3	-
Isaeidae amphipods	19	15	9
Ampelisca sp.	-	5	-
Pontogeneia sp.	-	1	2
MOLLUSCA			
GASTROPODA			
Batillaria sp.	-	-	1
species indeterminate	1	-	2

TABLE B-2-3 Cont'd:

STATION: A 8

ORGANISM	Sample No. 1	2	3
BIVALVIA			
Solen sicarius	1	1	2
Axinopsis serricata	7	4	27
Macoma sp.	-	2	-
Macoma juveniles	5	-	11
Nuculana minuta	5	-	5
Kellia suborbicularis	6	1	34
Protothaca sp.	-	1	-
Clinocardium sp.	-	-	2
Nucula tenuis	-	-	12
Lyonsia sp.	-	-	1
Mya arenaria	-	-	1
Yoldia sp.	-	-	2
ECHINODERMATA			
OPHIUROIDEA			
juveniles	8	1	3
damaged specimens	2	4	-
HOLOTHUROIDEA			
Pentamera sp.	-	-	1
TOTAL NUMBER OF ORGANISMS	269	224	358
TOTAL NUMBER OF TAXA	38	38	44
WET WEIGHT (g)	0.69	1.21	1.73

Sample Residue: Sample 1 - sand, gravel, plant debris, snail and clam shells
2 - sand, broken shell, plant debris, snail shells, fine wood debris
3 - fine plant debris, fine wood debris

TABLE B-2-4:

STATION: A 9

ORGANISM	Sample No. 1	2	3
NEMERTEA	-	-	2
PHORONIDA	1	-	-
ANNELIDA			
POLYCHAETA			
Armandia brevis	9	3	4
Lumbrineris latreilli	9	1	4
Ampharete sp.	8	5	3
Prionospio malmgreni	6	3	6
Maldanidae	4	1	-
Nephtys cornuta franciscana	3	-	9
Polydora ligni	3	1	2
Peisidice aspera	3	3	8
Pseudopolydora kempi japonica	3	-	-
Tharyx sp.	2	1	1
Glycinde picta	2	1	-
Nephtys sp.	2	-	3
Scoloplos armiger	2	9	9
Magelona sp.	-	2	-
Eteone longa	-	1	1
Capitellidae	-	1	-
Nereis sp.	-	-	9
Onuphis sp.	-	-	3
Hesionidae	-	-	11
Pectinaria sp.	-	-	1

TABLE B-2-4 Cont'd:

STATION: A 9

ORGANISM	Sample No. 1	2	3
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	1	-	-
Philomedes sp.	1	-	-
COPEPODA			
Calanoida copepods	1	-	-
NEBALIACEA			
Nebalia sp.	-	-	1
MYSIDACEA			
Neomysis sp.	1	-	-
CUMACEA			
Lamprops sp.	39	10	17
Oxyurostylis sp.	-	1	2
TANAIDACEA			
Leptochelia dubia	-	-	4
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	32	21	11
Lysianassidae amphipods	4	1	-
Caprella sp.	3	2	1
Photis sp.	3	1	4
Isaeidae amphipods	3	2	5
Oedicerotidae amphipods	2	6	15
Corophium sp.	-	1	-
Ampithoe sp.	-	-	5
Anisogammarus confervicolus	-	-	12
Pontogeneia sp.	-	-	11

TABLE B-2-4 Cont'd:

STATION: A 9

ORGANISM	Sample No. 1	2	3
DECAPODA			
Natantia	-	1	1
Pinnia sp.	-	-	1
Pugettia sp.	-	-	1
mysis	2	-	-
MOLLUSCA			
GASTROPODA			
Margarites? sp.	2	-	-
BIVALVIA			
Axinopsis serricata	11	8	3
Kellia suborbicularis	10	4	-
Macoma sp.	4	6	-
Macoma juveniles	-	-	3
Nucula tenuis	4	3	-
Yoldia sp.	1	-	-
Nuculana sp.	-	2	-
Mya arenaria	-	2	-
Clinocardium sp.	-	-	3
ECHINODERMATA			
OPHIUROIDEA			
juveniles	2	-	2
damaged specimens	3	4	1
HOLOTHUROIDEA			
Pentamera sp.	1	-	-

TABLE B-2-4 Cont'd:

STATION A 9

ORGANISM	Sample No. 1	2	3
CHORDATA			
PISCES			
larvae	-	5	-
TOTAL NUMBER OF ORGANISMS	187	112	179
TOTAL NUMBER OF TAXA	35	31	36
WET WEIGHT (g)	0.38	0.16	0.76

Sample Residue: Sample 1 - wood debris, plant debris, some shell pieces
2 - fine wood debris, shell pieces
3 - broken clam shells, sand, seaweed, plant debris

TABLE B-2-5

STATION: A 10

ORGANISM	Sample No. 1	2	3
<u>COELENTERATA</u>			
ANTHOZOA			
Ptilosarcus gurneyi	-	1	-
<u>PHORONIDA</u>	-	-	1
<u>ANNELIDA</u>			
POLYCHAETA			
Scoloplos armiger	7	8	9
Lumbrineris latreilli	4	2	-
Pseudopolydora kempi japonica	2	-	-
Glycinde picta	1	2	1
Armandia brevis	1	4	2
Prionospio malmgreni	1	5	7
Magelona sp.	1	-	-
Ampharete sp.	1	10	3
Eteone longa	1	1	-
Hesionidae polychaetes	-	4	-
Maldanidae polychaetes	-	2	-
Tharyx sp.	-	1	-
Pectinaria sp.	-	1	1
Peisidice aspera	-	1	-
Polydora ligni	-	1	6
Spionidae damaged	-	1	-
<u>ARTHROPODA</u>			
CUMACEA			
Lamprops sp.	8	10	6

TABLE B-2-5 Cont'd:

STATION: A 10

ORGANISM	Sample No. 1	2	3
CUMACEA Cont'd.			
Cumella vulgaris	-	1	-
Oxyurostylis sp.	1	-	-
TANAIDACEA			
Leptochelia dubia	-	1	-
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	21	87	25
Lysianassidae amphipods	11	18	7
Ampelisca sp.	1	-	-
Anisogammarus confervicolus	1	2	1
Photis sp.	-	4	-
Oedicerotidae amphipods	-	3	4
Isaeidae amphipods	-	4	-
DECAPODA			
Cancer sp.	-	1	-
zoea	-	3	-
MOLLUSCA			
GASTROPODA			
Margarites? sp.	11	-	25
BIVALVIA			
Macoma sp.	2	-	1
Macoma juveniles	11	10	2
Axinopsis serricata	7	-	4
Kellia suborbicularis	3	1	9
Clinocardium sp.	1	-	-

TABLE B-2-5 Cont'd:

STATION: A 10

ORGANISM	Sample No. 1	2	3
BIVALVIA Cont'd.			
Nucula tenuis	-	-	1
Solen sicarius	-	1	-
Mya arenaria	-	-	1
ECHINODERMATA			
OPHIUROIDEA			
damaged specimens	2	-	-
juveniles	-	2	6
CHORDATA			
PISCES			
larvae	-	1	-
TOTAL NUMBER OF ORGANISMS	99	193	122
TOTAL NUMBER OF TAXA	21	31	20
WET WEIGHT (g)	0.27	0.50	0.29

Sample Residue: Sample 1 - small wood pieces, broken shell, organic debris
2 - sand, plant pieces, plant debris, broken shells, snail shells, empty barnacles
3 - shell, fine wood debris

TABLE B-2-6:

STATION: A 11

ORGANISM	Sample No. 1	2	3
COELENTERATA			
HYDROZOA			
Phialidium sp.	-	1	-
ANNELIDA			
POLYCHAETA			
Scoloplos armiger	11	1	5
Tharyx sp.	3	1	3
Onuphis sp.	1	3	2
Armandia brevis	1	1	-
Prionospio malmgreni	1	-	-
Spiophanes bombyx	1	-	1
Lumbrineris latreilli	1	1	-
Ampharete sp.	1	1	-
Peisidice aspera	-	1	-
Pseudopolydora kempi japonica	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	-	-	2
CUMACEA			
Lamprops sp.	2	4	7
Cumella vulgaris	1	-	2
Oxyurostylis sp.	-	-	1
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	60	37	44

TABLE B-2-6 Cont'd:

STATION: A 11

ORGANISM	Sample No. 1	2	3
AMPHIPODA Cont'd.			
Lysianassidae amphipods	18	12	4
Oedicerotidae amphipods	6	-	5
Photis sp.	1	1	-
Ampelisca sp.	-	1	-
DECAPODA			
zoea	1	1	1
MOLLUSCA			
GASTROPODA			
Margarites? sp.	15	14	13
Trophonopsis sp.	-	1	-
BIVALVIA			
Axinopsis serricata	2	1	-
Kellia suborbicularis	2	1	1
Macoma juveniles	-	1	1
Clinocardium sp.	-	1	-
Mya arenaria	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
juveniles	7	9	2
CHORDATA			
PISCES			
larvae	-	1	1

TABLE B-2-6 Cont'd:

STATION: A 11

ORGANISM	Sample No. 1	2	3
TOTAL NUMBER OF ORGANISMS	135	96	96
TOTAL NUMBER OF TAXA	19	23	18
WET WEIGHT (g)	0.89	0.28	0.27

Sample Residue: Sample 1 - fine plant debris, fine wood debris, sand
2 - sand, shell, fine plant debris, fine wood debris, empty polychaete tubes
3 - sand, broken shells, fine plant debris

TABLE B-2-7

STATION: B 6

ORGANISM	Sample No. 1	2	3
<u>ASCHELMINTHES</u>			
NEMATODA	2	-	-
<u>ANNELIDA</u>			
POLYCHAETA			
Ampharete sp.	47	28	24
Spionidae immature	27	-	-
Scoloplos armiger	8	-	3
Prionospio malmgreni	7	-	1
Nephtys cornuta franciscana	6	-	-
Peisidice aspera	6	2	-
Tharyx sp.	3	-	2
Nephtys sp.	3	1	2
Owenia collaris	1	2	3
Glycinde picta	1	-	1
Lumbrineris latreilli	1	-	-
Nereis sp.	-	2	1
OLIGOCHAETA	4	-	-
<u>ARTHROPODA</u>			
CIRRIPEDIA			
Balanus sp.	-	-	5
CUMACEA			
Lamprops sp.	153	6	190
Diastylopsis sp.	4	-	2
Cumella vulgaris	2	-	2

TABLE B-2-7 Cont'd:

STATION: B 6

ORGANISM	Sample No. 1	2	3
ISOPODA			
Synidotea nebulosa	4	39	9
Pentidotea resecta	-	8	2
AMPHIPODA			
Atylus sp.	21	-	21
Photis sp.	21	48	20
Isaeidae amphipods	23	-	2
Ampithoe sp.	6	12	13
Oedicerotidae amphipods	7	-	6
Lysianassidae amphipods	3	-	2
Corophium sp.	4	-	1
Caprella sp.	1	-	-
Anisogammarus confervicolus	-	3	-
DECAPODA			
Cancer sp.	-	1	-
Crangon sp.	1	-	1
MOLLUSCA			
GASTROPODA			
Gastropteron sp.	7	-	1
species indeterminate	-	29	1
BIVALVIA			
Macoma sp.	-	-	2
Macoma juveniles	19	9	15
Mytilus edulis	-	95	20
Clinocardium sp.	-	9	2
Kellia suborbicularis	-	-	2

TABLE B-2-7 Cont'd:

STATION: B 6

ORGANISM	Sample No. 1	2	3
ECHINODERMATA			
OPHIUROIDEA			
juveniles	1	1	1
HOLOTHUROIDEA			
Pentamera sp.	-	-	1
CHORDATA			
PISCES			
larvae	3	-	-
TOTAL NUMBER OF ORGANISMS	396	295	358
TOTAL NUMBER OF TAXA	30	17	30
WET WEIGHT (g)	1.16	7.00	2.10

Sample Residue: Sample 1 - eggs, eelgrass, brown algae, sand, empty polychaete tubes, empty clam shells
2 - eggs, gravel, eelgrass, sea lettuce, empty polychaete tubes
3 - sand, eelgrass, empty polychaete tubes, broken and empty clam shells, sea lettuce

TABLE B-2-8:

STATION: B 7

ORGANISM	Sample No. 1	2	3
ANNELIDA			
POLYCHAETA			
Nephtys cornuta franciscana	43	11	45
Armandia brevis	14	-	6
Lumbrineris latreilli	5	6	5
Nephtys sp.	2	1	2
Onuphis sp.	1	-	-
Peisidice aspera	1	-	2
Scoloplos armiger	8	10	4
Glycinde picta	-	2	1
Prionospio malmgreni	-	2	2
Ampharete sp.	-	2	1
Prionospio cirrifera	-	1	3
Scalibregma inflatum	-	-	1
Eteone longa	-	-	1
Terebellides stroemi	-	-	1
Polydora ligni	-	-	1
Owenia collaris	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	3	2	-
Philomedes sp.	1	-	-
MYSIDACEA			
juveniles	-	1	-
CUMACEA			
Lamprops sp.	57	18	40
Diastylopsis sp.	9	2	1
Oxyurostylis sp.	-	2	-

TABLE B-2-8 Cont'd:

STATION: B 7

ORGANISM	Sample No. 1	2	3
ISOPODA			
Synidotea nebulosa	1	1	1
AMPHIPODA			
Lysianassidae amphipods	30	8	10
Paraphoxus sp. (*Trichophoxus*? sp.)	17	6	10
Atylus sp.	16	2	7
Ampithoe sp.	16	-	-
Ampelisca sp.	4	2	7
Oedicerotidae amphipods	3	5	-
Caprella sp.	2	-	3
Isaeidae amphipods	-	12	-
Photis sp.	-	-	10
Corophium sp.	-	-	17
DECAPODA			
zoea	-	3	-
MOLLUSCA			
GASTROPODA			
Polinices sp.	-	1	-
BIVALVIA			
Axinopsis serricata	58	19	58
Macoma sp.	-	6	-
Macoma juveniles	10	14	14
Nucula tenuis	6	3	8
Kellia suborbicularis	3	4	13
Mytilus edulis	-	1	-
Lyonsia sp.	-	-	1
Solen sicarius	-	-	1

TABLE B-2-8 Cont'd:

STATION: B 7

ORGANISM	Sample No. 1	2	3
ECHINODERMATA			
OPHIUROIDEA			
juveniles	15	12	13
damaged specimens	-	3	8
HOLOTHUROIDEA			
Pentamera sp.	-	-	1
TOTAL NUMBER OF ORGANISMS	325	162	299
TOTAL NUMBER OF TAXA	24	28	34
WET WEIGHT (g)	1.34	0.70	0.80

Sample Residue: Sample 1 - organic debris, sand, broken shell
2 - mud, sand, polychaete tubes, empty broken shells
3 - mud, shell, organic debris

TABLE B-2-9:

STATION: B 8

ORGANISM	Sample No. 1	2	3[1]
NEMERTEA	8	1	-
ANNELIDA			
POLYCHAETA			
Nephtys cornuta franciscana	53	204	196
Lumbrineris latreilli	33	55	52
Terebellides stroemi	7	1	-
Cossura sp.	6	14	4
Glycinde picta	5	10	8
Capitellidae	3	2	-
Tharyx sp.	2	5	-
Scoloplos armiger	2	4	-
Sternaspis fossor	1	1	1
Laonice cirrata	1	4	1
Ampharete sp.	1	1	-
Eteone longa	1	1	-
Maldanidae	1	3	4
Prionospio malmgreni	1	12	4
Hesionidae	-	1	-
Peisidice aspera	-	5	16
Prionospio pinnata	-	1	-
SIPUNCULIDA			
Dendrostoma sp.	1	-	-
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	1	2	-
Philomedes sp.	-	1	-

TABLE B-2-9 Cont'd:

STATION: B 8

ORGANISM	Sample No. 1	2	3[1]
COPEPODA			
Calanoida copepods	1	-	-
MYSIDACEA			
juveniles	-	43	-
CUMACEA			
Lamprops sp.	37	62	92
Oxyurostylis sp.	6	8	20
Diastylopsis sp.	5	14	12
Cumella vulgaris	4	1	-
ISOPODA			
Synidotea nebulosca	2	4	-
AMPHIPODA			
Photis sp.	40	18	92
Ampithoe sp.	35	10	28
Corophium sp.	32	15	-
Isaeidae amphipods	29	10	20
Lysianassidae amphipods	27	9	16
Atylus sp.	11	26	32
Oedicerotidae amphipods	7	11	16
Paraphoxus sp. (*Trichophoxus*? sp.)	3	-	-
Caprella sp.	-	2	-
Pontogeneia sp.	-	-	4
DECAPODA			
Crangon sp.	2	-	
Pinnixa sp.	-	1	-

TABLE B-2-9 Cont'd:

STATION: B 8

ORGANISM	Sample No. 1	2	3[1]
MOLLUSCA			
GASTROPODA			
Gastropteron sp.	2	1	1
Turbonilla sp.	-	1	-
BIVALVIA			
Axinopsis serricata	23	35	36
Nucula tenuis	20	17	20
Nuculana minuta	16	6	4
Macoma juveniles	3	6	4
Kellia suborbicularis	1	-	-
Lyonsia sp.	1	-	-
Mytilus edulis	-	-	4
ECHINODERMATA			
OPHIUROIDEA			
juveniles	-	11	-
damaged specimens	2	17	8
TOTAL NUMBER OF ORGANISMS	463	656	695
TOTAL NUMBER OF TAXA	40	43	26
WET WEIGHT (g)	3.08	4.29	4.56

Sample Residue: Sample 1 - grey sand, mud, empty polychaete tubes
2 - empty polychaete tubes, organic matter, plant pieces
3 - grey sand, empty polychaete tubes, mud

[1] 1/4 sample extrapolated to a whole sample

TABLE B-2-10:

STATION: B 9

ORGANISM	Sample No. 1	2	3
COELENTERATA			
HYDROZOA			
Phialidium sp.	-	-	1
PLATYHELMINTHES			
TURBELLARIA	2	-	-
NEMERTEA	2	1	2
ANNELIDA			
POLYCHAETA			
Armandia brevis	59	24	-
Scoloplos armiger	29	17	8
Polydora ligni	10	1	-
Manayunkia aestuarina	7	-	-
Lumbrineris latreilli	6	-	3
Nephtys sp.	3	1	1
Nephtys cornuta franciscana	3	3	3
Peisidice aspera	3	1	1
Paraonides platybranchia	2	-	1
Glycinde picta	2	2	1
Laonice cirrata	2	-	-
Maldanidae	2	-	3
Eteone longa	1	1	-
Cossura sp.	1	-	-
Tharyx sp.	1	3	1
Scalibregma inflatum	1	-	-

TABLE B-2-10 Cont'd:

STATION: B 9

ORGANISM	Sample No. 1	2	3
POLYCHAETA Cont'd.			
Sabellidae	-	3	1
Prionospio malmgreni	-	-	2
Ampharete sp.	7	5	3
Onuphis sp.	-	-	1
Spiophanes bombyx	-	-	1
ARTHROPODA			
OSTRACODA			
Philomedes sp.	1	-	-
COPEPODA			
Calanoida copepoda	-	1	1
MYSIDACEA			
juveniles	-	1	2
CUMACEA			
Lamprops sp.	42	24	20
Oxyurostylis sp.	-	-	1
ISOPODA			
Synidotea nebulosa	-	1	-
AMPHIPODA			
Lysianassidae amphipods	14	1	8
Photis sp.	12	7	2
Paraphoxus sp. (*Trichophoxus*? sp.)	6	10	24
Ampithoe sp.	2	-	-
Ampelisca sp.	1	7	-

TABLE B-2-10 Cont'd:

STATION: B 9

ORGANISM	Sample No. 1	2	3
AMPHIPODA Cont'd.			
Oedicerotidae amphipods	1	3	2
Atylus sp.	-	2	-
Isaeidae amphipods	-	5	-
DECAPODA			
zoea	2	2	3
mysis	1	1	-
MOLLUSCA			
GASTROPODA			
Gastropteron sp.	1	-	-
Margarites? sp.	-	4	1
BIVALVIA			
Macoma sp.	-	4	13
Macoma juveniles	4	3	-
Nucula tenuis	1	2	1
Axinopsis serricata	2	10	7
Kellia suborbicularis	3	3	-
Solen sicarius	-	1	-
Mya arenaria	-	3	4
Protothaca sp.	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
Ophiura sp.	-	-	1
juveniles	5	9	-
damaged specimens	9	-	4

TABLE B-2-10 Cont'd:

STATION: B 9

ORGANISM	Sample No. 1	2	3
CHORDATA			
PISCES			
larvae	1	-	2
TOTAL NUMBER OF ORGANISMS	251	167	129
TOTAL NUMBER OF TAXA	37	24	33
WET WEIGHT (g)	1.16	0.61	0.65

Sample Residue: Sample 1 - broken shell, wood pieces, sand, clay, gravel, plant pieces
2 - small wood pieces
3 - sand, empty shells, empty polychaete tubes

TABLE B-2-11:

STATION: A 10

ORGANISM	Sample No. 1	2	3
CTENOPHORA			
TENTACULATA			
Pleurobrachia sp.	-	1	-
ASCHELMINTHES			
NEMATODA	-	1	-
ANNELIDA			
POLYCHAETA			
Armandia brevis	5	2	-
Scoloplos armiger	2	6	1
Glycinde picta	1	1	2
Paraonides platybranchia	1	1	-
Spionidae immature	1	1	-
Spiophanes bombyx	-	3	1
Nephtys sp.	-	1	2
Syllidae	-	1	-
Prionospio malmgreni	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	-	1	2
COPEPODA			
Calanoida copepods	-	2	3

TABLE B-2-11 Cont'd:

STATION: B 10

ORGANISM	Sample No. 1	2	3
MYSIDACEA			
juveniles	-	1	-
CUMACEA			
Lamprops sp.	4	3	3
Cumella vulgaris	-	1	1
ISOPODA			
Synidotea nebulosa	-	1	-
AMPHIPODA			
Lysianassidae amphipods	14	19	5
Oedicerotidae amphipods	6	2	4
Paraphoxus sp. (*Trichophoxus*? sp.)	5	6	3
Photis sp.	-	1	1
Caprella sp.	-	1	-
Anisogammarus confervicolus	-	-	1
DECAPODA			
zoea	4	11	4
mysis	-	-	2
GASTROPODA			
Margarites? sp.	-	2	4
BIVALVIA			
Macoma sp.	10	22	4
Macoma juveniles	-	8	6
Kellia suborbicularis	2	1	-
Axinopsis serricata	1	-	4
Clinocardium sp.	-	1	-
Solen sicarius	-	-	1
Acila castrensis	-	-	1

TABLE B-2-11 Cont'd:

STATION: B 10

ORGANISM	Sample No. 1	2	3
ECHINODERMATA			
OPHIUROIDEA			
juveniles	5	3	6
CHORDATA			
TUNICATA			
Larvacea	-	1	-
PISCES			
larvae	-	1	-
TOTAL NUMBER OF ORGANISMS	61	106	62
TOTAL NUMBER OF TAXA	14	29	21
WET WEIGHT (g)	0.31	0.58	0.97

Sample Residue: Sample 1 - gravel
2 - sand, empty polychaete tubes
3 - sand, empty polychaete tubes

TABLE B-2-12:

STATION: B 11

ORGANISM	Sample No. 1	2	3
ANNELIDA			
POLYCHAETA			
Scoloplos armiger	4	-	8
Armandia brevis	4	-	5
Paraonides platybranchia	2	-	-
Tharyx sp.	1	-	1
Nephtys sp.	-	1	1
Lumbrineris latreilli	-	-	4
Glycinde picta	-	-	2
Spiophanes bombyx	-	-	2
Ampharete sp.	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	1	1	1
Philomedes sp.	-	-	1
COPEPODA			
Calanoida copepods	3	1	-
CUMACEA			
Lamprops sp.	2	-	6
Cumella vulgaris	1	-	1
ISOPODA			
Synidotea nebulosa	-	-	1
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	21	7	33

TABLE B-2-12 Cont'd:

STATION: B 11

ORGANISM	Sample No. 1	2	3
AMPHIPODA Cont'd.			
Lysianassidae amphipods	12	9	2
Oedicerotidae amphipods	1	3	2
Ampelisca sp.	-	1	-
Photis sp.	-	1	-
Ampithoe sp.	-	-	2
DECAPODA			
zoea	14	9	2
mysis	2	1	2
MOLLUSCA			
GASTROPODA			
Margarites? sp.	15	6	29
BIVALVIA			
Kellia suborbicularis	1	-	1
Macoma juveniles	-	5	2
ECHINODERMATA			
OPHIUROIDEA			
juveniles	1	6	1
damaged specimens	2	-	1
CHORDATA			
TUNICATA			
Larvacea	-	1	-

TABLE B-2-12 Cont'd:

STATION: B 11

ORGANISM	Sample No. 1	2	3
PISCES			
larvae	-	1	-
TOTAL NUMBER OF ORGANISMS	87	53	111
TOTAL NUMBER OF TAXA	17	15	24
WET WEIGHT (g)	0.16	0.14	0.40

Sample Residue: Sample 1 - coarse sand, fine wood debris
2 - sand, empty polychaete tubes, fine wood debris
3 - sand, empty polychaete tubes, fine wood debris

TABLE B-2-13:

STATION: C 4

ORGANISM	Sample No. 1	2	3
ANNELIDA			
POLYCHAETA			
Spionidae	77	48	63
Owenia collaris	14	20	9
Scoloplos armiger	7	8	11
Polydora ligni	7	3	3
Ampharete sp.	4	5	11
Nephtys cornuta franciscana	3	-	1
Nephtys sp.	2	3	1
Lumbrineris latreilli	1	-	-
Hesionidae	1	-	-
Peisidice aspera	1	-	-
Onuphis sp.	-	1	-
Spiophanes bombyx	-	7	-
Eteone longa	-	1	1
Glycinde picta	-	-	1
Tharyx sp.	-	-	2
ARTHROPODA			
OSTRACODA			
Philomedes sp.	-	-	1
NEBALIACEA			
Nebalia sp.	1	-	-
CUMACEA			
Lamprops sp.	33	27	37
Diastylopsis sp.	6	16	15
Cumella vulgaris	-	1	2

TABLE B-2-13 Cont'd:

STATION: C 4

ORGANISM	Sample No. 1	2	3
ISOPODA			
Synidotea nebulosa	5	2	4
AMPHIPODA			
Atylus sp.	16	21	13
Ampelisca sp.	14	16	4
Photis sp.	12	18	11
Paraphoxus sp. (*Trichophoxus*? sp.)	1	-	1
Oedicerotidae amphipods	1	2	3
Corophium sp.	1	-	1
Ampithoe sp.	-	9	1
Isaeidae amphipods	-	17	10
DECAPODA			
zoea	2	-	1
mysis	-	-	1
MOLLUSCA			
BIVALVIA			
Macoma sp.	2	4	1
Macoma juveniles	255	205	210
Mya arenaria	4	-	6
Kellia suborbicularis	12	2	9
Nucula tenuis	-	-	6
ECHINODERMATA			
OPHIUROIDEA			
juveniles	2	-	2

TABLE B-2-13 Cont'd:

STATION: C 4

ORGANISM	Sample No. 1	2	3
CHORDATA			
PISCES			
larvae	-	1	2
TOTAL NUMBER OF ORGANISMS	485	437	444
TOTAL NUMBER OF TAXA	25	22	31
WET WEIGHT (g)	0.97	0.75	0.80

Sample Residue: Sample 1 - empty polychaete sand tubes
2 - sand, empty polychaete sand tubes
3 - sand, empty polychaete sand tubes

TABLE B-2-14:

STATION: C 5

ORGANISM	Sample No. 1	2	3
ANNELIDA			
POLYCHAETA			
Polydora ligni	14	5	3
Hesionidae	11	11	-
Spionidae	6	14	-
Ampharete sp.	2	-	1
Spiophanes bombyx	2	1	-
Scoloplos armiger	2	2	2
Maldanidae	1	-	-
Eteone longa	-	1	-
Nephtys sp.	-	1	-
Peisidice aspera	-	-	2
Onuphis sp.	-	-	1
Tharyx sp.	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	1	-	-
CIRRIPEDIA			
Balanus sp.	-	-	411
CUMACEA			
Lamprops sp.	16	24	24
Oxyurostylis sp.	1	1	1
Diastylopsis sp.	-	-	1
TANAIDACEA			
Leptochelia dubia	1	1	-

TABLE B-2-14 Cont'd:

STATION: C 5

ORGANISM	Sample No. 1	2	3
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	7	13	-
Lysianassidae amphipods	5	3	-
Ampelisca sp.	2	7	-
Photis sp.	2	-	1
Atylus sp.	1	-	8
Caprella sp.	-	1	1
Oedicerotidae amphipods	-	5	1
Isaeidae amphipods	-	2	6
Anisogammarus confervicolus	-	-	2
DECAPODA			
zoea	-	2	-
mysis	-	2	-
MOLLUSCA			
GASTROPODA			
Margarites? sp.	16	15	-
Turbonilla sp.	4	1	-
Batillaria sp.	-	-	1
BIVALVIA			
Macoma sp.	7	-	-
Macoma juveniles	385	251	3
Kellia suborbicularis	13	39	7
Lyonsia sp.	1	-	2
Clinocardium sp.	1	-	2
Axinopsis serricata	-	-	1

TABLE B-2-14 Cont'd:

STATION: C 5

ORGANISM	Sample No. 1	2	3
ECHINODERMATA			
OPHIUROIDEA			
juveniles	2	3	4
damaged specimens	-	1	5
CHORDATA			
PISCES			
larvae	1	1	-
TOTAL NUMBER OF ORGANISMS	532	407	489
TOTAL NUMBER OF TAXA	24	25	23
WET WEIGHT (g)	0.81	0.57	1.26

Sample Residue: Sample 1 - gravel
2 - sand, empty polychaete tubes
3 - sand, broken shells

TABLE B-2-15:

STATION: C 6

ORGANISM	Sample No. 1	2	3
NEMERTEA	2	1	-
ANNELIDA			
POLYCHAETA			
Armandia brevis	1	-	2
Tharyx sp.	1	1	2
Nephtys sp.	1	1	2
Glycinde picta	1	-	2
Spionidae	1	1	-
Hesionidae	1	-	-
Polydora ligni	1	-	-
Spiophanes bombyx	1	1	2
Scoloplos armiger	-	2	9
Prionospio cirrifera	-	1	-
Ampharete sp.	-	1	3
Paraonides platybranchia	-	1	1
Eteone longa	-	-	1
Sabellidae	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	1	1	1
COPEPODA			
Calanoida copepods	-	-	1
MYSIDACEA			
juveniles	1	-	4

TABLE B-2-15 Cont'd:

STATION: C 6

ORGANISM	Sample No. 1	2	3
CUMACEA			
Lamprops sp.	23	35	10
Diastylopsis sp.	-	1	-
ISOPODA			
Synidotea nebulosa	1	-	-
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	9	7	37
Oedicerotidae amphipods	1	1	4
Corophium sp.	1	-	-
Photis sp.	1	-	3
Anisogammarus confervicolus	1	-	2
Lysianassidae amphipods	-	9	8
Atylus sp.	-	1	1
Isaeidae amphipods	-	3	-
Ampelisca sp.	-	-	1
DECAPODA			
zoea	12	11	28
mysis	7	3	-
MOLLUSCA			
GASTROPODA			
Margarites? sp.	2	5	3
Trophonopsis sp.	-	-	1
BIVALVIA			
Macoma juveniles	48	3	3
Kellia suborbicularis	10	-	8

TABLE B-2-15 Cont'd:

STATION: C 6

ORGANISM	Sample No. 1	2	3
BIVALVIA Cont'd.			
Nucula tenuis	1	-	-
Solen sicarius	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
juveniles	4	3	10
CHORDATA			
PISCES			
larvae	3	2	2
TOTAL NUMBER OF ORGANISMS	136	96	152
TOTAL NUMBER OF TAXA	26	24	28
WET WEIGHT (g)	0.33	0.14	0.27

Sample Residue: Sample 1 - gravel, empty polychaete tubes
2 - coarse sand
3 - sand

TABLE B-2-16:

STATION: C 7

ORGANISM	Sample No. 1	2	3
NEMERTEA	1	-	5
ANNELIDA			
POLYCHAETA			
Scoloplos armiger	15	1	2
Armandia brevis	10	-	5
Tharyx sp.	4	1	-
Spiophanes bombyx	3	1	-
Magelona sp.	3	-	-
Glycinde picta	2	-	-
Polydora ligni	2	1	-
Onuphis sp.	1	-	-
Maldanidae	1	-	-
Peisidice aspera	1	-	-
Ampharete sp.	1	1	4
Owenia collaris	1	-	-
Paraonides platybranchia	1	1	-
Nephtys cornuta franciscana	1	-	-
Lumbrineris latreilli	-	-	1
Sabellidae	-	-	8
Prionospio cirrifera	-	-	1
Prionospio malmgreni	-	-	2
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	2	-	2
NEBALIACEA			
Nebalia sp.	1	-	-

TABLE B-2-16 Cont'd:

STATION: C 7

ORGANISM	Sample No. 1	2	3
MYSIDACEA			
juveniles	8	1	-
CUMACEA			
Lamprops sp.	58	23	1
Oxyurostylis sp.	1	-	-
Cumella vulgaris	1	-	1
ISOPODA			
Synidotea nebulosa	1	1	-
AMPHIPODA			
Paraphoxus sp. (*Trichophoxus*? sp.)	17	12	1
Atylus sp.	12	-	-
Lysianassidae amphipods	11	-	2
Photis sp.	10	-	-
Oedicerotidae amphipods	6	3	-
Pontogeneia sp.	4	-	2
Isaeidae amphipods	-	3	6
Anisogammarus confervicolus	-	1	-
Caprella sp.	-	-	1
Ampithoe sp.	-	-	8
DECAPODA			
zoea	1	2	-
MOLLUSCA			
GASTROPODA			
Margarites? sp.	3	-	1
Gastropteron sp.	1	-	-

TABLE B-2-16 Cont'd:

STATION: C 7

ORGANISM	Sample No. 1	2	3
GASTROPODA Cont'd.			
Batillaria sp.	-	1	-
Nassarius sp.	-	-	1
BIVALVIA			
Macoma sp.	3	-	-
Macoma juveniles	14	19	2
Kellia suborbicularis	12	14	5
Nucula tenuis	2	-	-
Axinopsis serricata	1	-	4
Solen sicarius	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
juveniles	7	5	-
damaged specimens	12	-	1
HOLOTHUROIDEA			
Pentamera sp.	1	-	-
CHORDATA			
PISCES			
larvae	2	2	1
TOTAL NUMBER OF ORGANISMS	238	94	67
TOTAL NUMBER OF TAXA	39	20	24
WET WEIGHT (g)	0.43	0.14	0.09

Sample Residue: Sample 1 - fine wood debris, coarse sand
2 - sand, fine wood debris
3 - broken shell, wood debris

TABLE B-2-17:

STATION: C 6

ORGANISM	Sample No. 1	2	3
NEMERTEA	1	-	-
ANNELIDA			
POLYCHAETA			
Armandia brevis	2	4	-
Glycinde picta	1	1	-
Scoloplos armiger	-	6	1
Lumbrineris latrelli	-	4	1
Ampharete sp.	-	2	-
Peisidice aspera	-	2	-
Scalibregma inflatus	-	1	-
Onuphis sp.	-	1	-
Eteone longa	-	1	-
Tharyx sp.	-	-	1
Spiophanes bombyx	-	-	1
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	4	1	-
COPEPODA			
Calanoida copepods	2	-	1
CUMCACEA			
Lamprops sp.	4	2	2
Oxyurostylis sp.	-	1	1
Cumella vulgaris	-	1	-

TABLE B-2-17 Cont'd:

STATION: C 8

ORGANISM	Sample No. 1	2	3
ISOPODA			
Synidotea nebulosa	-	3	-
AMPHIPODA			
Lysianassidae amphipods	27	4	7
Paraphoxus sp. (*Trichophoxus*? sp.)	12	19	5
Oedicerotidae amphipods	1	-	-
Ampithoe sp.	-	13	-
Caprella sp.	-	4	-
Isaeidae amphipods	-	18	-
DECAPODA			
zoea	2	-	1
MOLLUSCA			
GASTROPODA			
Margarites? sp.	3	1	1
BIVALVIA			
Macoma sp.	-	-	1
Macoma juveniles	62	5	12
Kellia suborbicularis	5	12	2
Clinocardium sp.	1	2	-
Axinopsis serricata	-	1	-
Mya arenaria	-	1	-
ECHINODERMATA			
OPHIUROIDEA			
juveniles	-	2	-
damaged specimens	-	3	1

TABLE B-2-17 Cont'd:

STATION: C 8

ORGANISM	Sample No. 1	2	3
CHORDATA			
PISCES			
larvae	-	1	1
TOTAL NUMBER OF ORGANISMS	127	116	39
TOTAL NUMBER OF TAXA	14	28	15
WET WEIGHT (g)	0.45	0.32	0.04

Sample Residue: Sample 1 - sand, broken shell
2 - fine wood debris, broken shell
3 - gravel, fine wood debris, broken shell

TABLE B-2-18:

STATION: C 9

ORGANISM	Sample No. 1	2	3
COELENTERATA			
HYDROZOA			
Phialidium sp.	1	-	-
ANNELIDA			
POLYCHAETA			
Tharyx sp.	2	-	2
Ampharete sp.	2	11	-
Pseudopolydora kempi japonica	2	-	1
Scoloplos armiger	1	1	-
Paraonides platybranchia	1	1	-
Lumbrineris latreilli	1	2	-
Syllidae	1	-	-
Armandia brevis	-	3	1
Onuphis sp.	-	3	-
Maldanidae	-	3	-
Branchiomma sp.	-	2	-
Terebellides stroemi	-	2	-
Scalibregma inflatum	-	1	-
Glycinde picta	-	2	-
Nephtys cornuta franciscana	-	1	-
Peisidice aspera	-	1	-
Sabellidae	-	1	-
ARTHROPODA			
OSTRACODA			
Conchoecia sp.	-	1	1

TABLE B-2-18 Cont'd

STATION: C 9

ORGANISM	Sample No. 1	2	3
COPEPODA			
Calanoida copepods	2	1	1
MYSIDACEA			
juveniles	2	1	-
CUMACEA			
Cumella vulgaris	-	24	-
Lamprops sp.	-	4	-
Oxyurostylis sp.	-	3	-
AMPHIPODA			
Lysianassidae amphipods	20	8	31
Paraphoxus sp. (*Trichophoxus*? sp.)	6	13	4
Oedicerotidae amphipods	1	-	1
Photis sp.	-	5	-
Ampelisca sp.	-	3	-
Isaeidae amphipods	-	2	-
DECAPODA			
mysis	-	1	1
MOLLUSCA			
GASTROPODA			
Margarites? sp.	3	1	3
Trophonopsis sp.	-	1	-
BIVALVIA			
Macoma sp.	10	4	2
Macoma juveniles	4	-	11

TABLE B-2-18 Cont'd:

STATION: C 9

ORGANISM	Sample No. 1	2	3
BIVALVIA Cont'd.			
Kellia suborbicularis	3	2	-
Axinopsis serricata	-	-	1
ECHINODERMATA			
OPHIUROIDEA			
juveniles	6	7	7
HOLOTHUROIDEA			
Pentamera sp.	-	1	-
TOTAL NUMBER OF ORGANISMS	68	116	67
TOTAL NUMBER OF TAXA	17	32	12
WET WEIGHT (g)	0.16	0.13	0.20

Sample Residue: Sample 1 - fine wood debris, empty polychaete tubes
2 - sand, fine wood debris
3 - sand, empty polychaete tubes

ANNEX B-3

SIZES OF CRABS COLLECTED
ROBERTS BANK
June 22 & 29, 1977

TABLE B-3-1 SIZES OF *Cancer magister* COLLECTED 22 JUNE 1977, INSHORE OF WESTSHORE TERMINAL

Male		Female	
Carapace width (mm)	weight (gm)	Carapace width (mm)	weight (gm)
173	697	148	440
160	521	143	380
154	486	132	328
152	476	132	321
150	480	132	304
150	446	129	328
149	448	129	390
148	464	128	354
146	368	126	290
145	461	125	271
145	438	120	260
144	424	114	232
144	402	114	224
143	420	105	137
136	314	90	98
$\bar{x} \pm$ S.D. 149 $\pm$ 9	456 $\pm$ 84	124 $\pm$ 14	283 $\pm$ 88

TABLE B-3-2 SIZES OF *Hemigrapsus nudus* COLLECTED 22 JUNE 1977, INSHORE OF WESTSHORE TERMINAL

Male				Female	
Carapace width (mm)	weight (gm)	Carapace width (mm)	weight (gm)	Carapace width (mm)	weight (gm)
35	20.6	25	8.2	29	8.9
32	14.9	25	7.7	29	8.0
32	14.2	25	7.5	28	8.5
29	11.1	25	7.4	27	7.6
29	10.5	25	7.1	26	7.0
29	10.1	25	7.1	26	6.9
29	8.4	25	7.1	26	6.5
28	11.8	25	6.7	25	6.0
28	9.3	25	6.5	24	5.8
28	9.1	25	6.4	24	5.6
28	9.1	24	6.9	23	4.7
28	8.7	24	6.8	n = 11	
27	10.4	24	5.9	size	
]7	9.4	24	5.8	$\bar{x} \pm$ S.D. = 26.1 $\pm$ 2.0	
27	9.5	24	5.8	weight	
27	9.1	24	5.6	$\bar{x} \pm$ S.D. = 6.9 $\pm$ 1.3	
27	9.0	23	6.2		
27	8.1	23	5.6		
27	8.0	23	5.3		
27	6.1	20	3.6		
26	9.0	n = 45			
26	8.7	size			
26	8.3	$\bar{x} \pm$ S.D. = 26.4 $\pm$ 2.7			
26	7.4	weight			
26	6.8	$\bar{x} \pm$ S.D. = 8.4 $\pm$ 2.9			

TABLE B-3-3 SIZES OF MALE *Cancer magister* COLLECTED 29 JUNE 1977 (see text for area description)

Area 1		Area 2		Area 3	
Carapace width (mm)	weight (gm)	Carapace width (mm)	weight (gm)	Carapace width (mm)	weight (gm)
163	529	160	583	161	577
162	543	160	510	160	594
161	556	159	597	160	578
160	624	159	555	160	522
160	536	159	526	160	468
159	575	158	617	159	604
159	555	158	555	159	572
158	589	158	536	159	564
158	568	158	508	158	574
158	560	157	535	158	538
158	498	156	513	158	516
157	530	155	525	158	516
157	527	155	518	157	575
156	527	153	449	156	489
156	523	152	534	155	561
156	515	n = 15		155	507
153	534			n = 16	
149	481				
n = 18					

n = 49

size $\bar{x} \pm$ S.D. = 158 $\pm$ 3

weight $\bar{x} \pm$ S.D. = 543 $\pm$ 37

ANNEX B-4

BIRD SPECIES OBSERVED

ANNEX B-4

LIST OF SPECIES OBSERVED OR CATEGORIES USED DURING FIELD OBSERVATIONS OF BIRDS, APRIL 22 - MAY 10, 1977

Common Name	Scientific Name
Common Loon	*Gavia immer*
Arctic Loon	*Gavia arctica*
Red-throated Loon	*Gavia stellata*
Loon sp.	*Gavia* sp.
Red-necked Grebe	*Podiceps grisegena*
Horned Grebe	*Podiceps auritus*
Western Grebe	*Aechmophorous occidentalis*
Double-crested Cormorant	*Phalacrocorax auritus*
Brant's Cormorant	*Phalacrocorax penicillatus*
Pelagic Cormorant	*Phalacrocorax pelagicus*
Cormorant Sp.	*Phalacrocorax* sp.
Great Blue Heron	*Ardea herodias*
Brant	*Branta bernicla*
Mallard	*Anas platyrhynchos*
Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
American Wigeon	*Anas americana*
Northern Shoveler	*Anas clypeata*
Greater Scaup	*Aythya marila*
Scaup sp.	*Aythya marila or Aythya affinis*
Common Goldeneye	*Bucephala clangula*
Barrow's Goldeneye	*Bucephala islandica*
Bufflehead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
Harlequin Duck	*Histrionicus histricnicus*
White-winged Scoter	*Melanitta deglandi*
Surf Scoter	*Melanitta perspicillata*
Black Scoter	*Melanitta nigra*
Scoter sp.	*Melanitta* sp.
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*
Unidentified Ducks	
Bald Eagle	*Haliaeetus leucocephalus*
Marsh Hawk	*Circus cyaneus*
Semi-palmated Plover	*Charadrius semipalmatus*
Killdeer	*Charadrius vociferus*
Dunlin	*Calidris alpina*
Western Sandpiper	*Calidris mauri*

Common Names	Scientific Name
Sanderling	*Calidris albal*
"Peeps"	Mostly *Calidris* spp.
Glaucous-winged Gull	*Laurus glaucescens*
Western Gull	*Laurus occidentalis*
Herring Gull	*Laurus argentatus*
California Gull	*Laurus californicus*
Ring-billed Gull	*Larus delawarensis*
Franklin's Gull	*Larus pipixcan*
Bonaparte's Gull	*Larus philadelphia*
Gull sp.	*Larus* sp.
Common Tern	*Sterna hirundol*
Forster's Tern	*Sterna forsteri*
Marbled Murrelet	*Brachyramphus marmoratus*
Murrelet sp.	One of several spp.
Rhinoceros Auklet	*Cerorhinca monocerata*
Hummingbird sp.	Probably *Selasphorus rufus*
Barn Swallow	*Hirundo rustica*
Tree Swallow	*Iridoprocne bicolor*
Common Raven	*Corvus corax*
Winter Wren	*Troglodytes troglodytes*
European Starling	*Sturnus vulgaris*
White-crowned Sparrow	*Zonotrichia leutophrys*
Song Sparrow	*Melospiza melodia*